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POTENTIAL HYDROELECTRIC POWER FOR STATE OWNED DAMS

WATER RESOURCES DIVISION
DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

STATE OF MONTANA

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

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Deadwood 26 mw - $3.6 million - cWh Average Annual

Round Prairie 52 mw $3.5 million - age Annual

Broadwater Units 14.4 mw $14.7 million

Feasibility Units 9.76 mw $13.3 million

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PREFACE

Excerpt from President Carter's message to Congress on The National Energy Plan:[1]

"New or additional hydroelectric generating capacity at existing dams could be installed at less than the cost of equivalent new coal or nuclear capacity. Many of these sites are small, but could generate 3 to 5 megawatts, and are located near major demand centers currently dependent on imported fuel oil. Installation of additional generating capacity at existing sites could conceivably add as much as 14,000 megawatts to the nation's generating potential."

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1 The National Energy Plan, dated April 29, 1977, page 73.

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SUMMARY CONCLUSIONS AND RECOMMENDATIONS

Summary

This report examines the potential engineering and economic feasibility of three small hydroelectric projects to be located at existing dams under the administration of Montana's Department of Natural Resources and Conservation. The projects were selected from forty water conservation projects on which statistical data had been compiled in a Report prepared by the Department[1/]. The sale of the power at the hydroelectric installations would assist the State to obtain revenues for maintenance and to possibly retire a portion of the unsecured debt for the water conservation projects.

The three projects selected for study were located on three separate drainage systems. A field reconnaissance was made of the project area in order to appraise the physical characteristics. A scheme of development for each site was prepared for the proposed power features along with modifications to the existing facilities where required.

An assessment of the potential energy that could be generated at each site was computed based on hydrological records and physical characteristics of the site. A computer program, simulating the seasonal flow characteristics of the watershed and operation of the plants, was used to perform the energy studies. The three projects combined indicated a potential generation of 105 million kilowatt-hours having an estimated market value in excess of $2,700,000 annually. This energy is equivalent to that produced by approximately 60,000 tons of coal in a modern coal-fired steam electric generating station.

An economic evaluation of costs and benefits

1/ State Water Conservation Projects, DNRC, March 1977.

indicates that the three projects as a group would result in a benefit-cost ratio of 1.62 to 1. The Federal Energy Regulatory Commission (formerly Federal Power Commission) has unofficially indicated that benefit-cost ratios of 0.70 to 1 are justifiable for construction in today's markets when comparing hydro power to a fossil fuel-fired plant where the latter's cost of energy will inflate with time.

Potential markets for this power were identified in this study as was a means of delivery of the energy to the power purchaser. Small entities may be desirous of obtaining power from these installations with the declining availability of power from the government projects.

Recommendations

1. The results of this study indicate that the State Department of Natural Resources and Conservation should consider prompt preparation of Preliminary Applications to the Federal Energy Regulatory Commission for each of the sites reviewed in this report to protect their priority in development of the sites.

2. Meetings should be initiated with potential power purchasers, and Bonneville Power Administration for possible transmission of the power.

3. After negotiation of a power purchase agreement, full application for Federal Energy Regulation Commission license should be prepared for each site, including geological exploration, preliminary design, and environmental impact report. Water rights applications, if necessary, and agreements with other governmental agencies should be negotiated.

4. As federal assistance programs for small hydroelectric projects become available, applications should be made to assist in the financing or to provide the front end money needed to initiate the projects.

CHAPTER I

INTRODUCTION

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INTRODUCTION

The State of Montana owns over forty water storage or distribution projects. Most of these projects were constructed by the State Water Conservation Board during the nationwide depression of the 1930's and drought in the late 1930's. The state agency responsible for the administration of the projects is the Water Resource Division of the Department of Natural Resources and Conservation. Their offices are located in Helena.

The projects are administered through contractual agreements with local water users associations. In most cases, the local water users operate the projects, with the Department providing a general review authority. Recovery of the State's investment in the projects has received little consideration until recently. The Department has been directed by legislature to recover as much of the previously unsecured debt as possible from the local water users associations. The Department is considering the possibility to generate hydroelectric power at some of their facilities as a way to assist in the return of this debt, and to assist in providing funds for capital expenditure to perform major rehabilitation of some of the projects which have deteriorated with age.

Previous Investigations

The dramatic increase in the cost of electrical energy generated by fossil-fuel power plants has substantially increased the value of hydroelectric power. Hydroelectric power is a renewable source of energy, pollution-free, that is currently being wasted at many of the State's projects. In view of this opportunity, The State Water Resources Division staff members and Tudor Engineering Company briefly reviewed the opportunities to generate power at all State Water

Projects. From the resulting report,[1] three projects were singled out for future study; a high head installation, a low head installation, and a project using an off-stream storage site. These projects provided a good opportunity to demonstrate methodology, procedures and economic feasibility of small hydroelectric projects.

Scope and Purpose

The three potential hydroelectric projects that were selected for study are located as follows:

a. Broadwater Dam on the Missouri River, Broadwater County; and

b. Deadman's Basin, an off-stream storage dam near the Musselshell River, Wheatland County; and

c. Painted Rocks Dam on the West Fork Bitterroot River, Ravalli County.

The studies presented in this report were prepared in accordance with the scope of work outlined by the Department. That scope is summarized as follows:

1. Review all available information regarding the existing facility which may affect the power generating potential including a field reconnaissance of the existing dams and appurtenances to verify reported conditions.

2. Study the hydroelectric generating potential of each site, including different generating capacity and alternative types of hydraulic turbines.

3. Prepare an evaluation of the potential markets for the sale of power and the legal constraints which might be imposed depending upon the purchaser of power.

4. Prepare cost estimates for the proposed work.

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[1] State Water Conservation Projects, Montana Dept. of Natural Resources and Conservation, March 1977.

5. Prepare an economic evaluation of costs and benefits of the recommended plans and financial analysis for potential recovery of investment.

6. Recommend an outline for future course of action.

Acknowledgements

Tudor Engineering Company is very appreciative of the assistance and cooperation extended to us by the representatives of the State of Montana during the preparation of this report. Without their timely assistance in data collection and furnishing reports and arranging field trips, this report could not have been prepared.

CHAPTER II

VALUE OF HYDROELECTRIC POWER

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VALUE OF HYDROELECTRIC POWER

GENERAL

The value of a hydroelectric project is usually determined by comparing it to the least cost alternative, consisting of some form of fossil-fuel generation capable of serving the same portion of the load-duration curve as was assumed for the hydroelectric project.

Events of the past five years have brought about a major upward increase in the value of hydroelectric power. The rising cost of oil domestically and on the international market has dramatically increased the cost of oil-fired electric energy. Similarly, the cost of coal-fired electrical generation has risen almost as rapidly as that of oil, because of the demand for this form of energy conversion, and because of the stringent environmental controls on stack emissions and on strip mines.

There are strong indications by the present administration that there will be a national policy to become energy self-sufficient by the mid-1980's and thus decrease our dependency on oil supplies from the Middle East. A national policy of energy self-sufficiency will have the short-and-long-term effect of increasing fossil fuel prices to even higher levels.

The generation of hydroelectric energy has three distinct advantages over other forms of generation; first, falling water, which is the potential energy for the hydraulic turbine, is a renewable resource which is not subject to depletion; second, hydroelectric energy can be stored daily, weekly and even monthly, and used for consumer load requirements when needed; and third, the efficiency of converting from potential energy to electrical energy for a hydroelectric plant is about 85 percent as compared to 35 percent for fossil-fuel generation.

DEFINITIONS USED

Some of the terms that are commonly used to describe the electrical loads for a given service area are energy, power, peak demand, average demand, load-duration curve, load factor, capacity factor, base load, run-of-river plant, spinning and wheeling. These terms as used in this report are defined below.

Energy

The classical definition of energy is the ability to do work or work. Both energy and work are measured in foot pounds; electrical generation and usage is measured in kilowatt-hours.

Power

The classical definition of power is rate of work or work done in a specified time. In electrical generation and usage the usual units of power are kilowatts (or mega-watts). However, in this report we use the term "power" interchangeably to represent both kilowatts and kilowatt-hours.

Peak Demand

Peak demand is the maximum demand in kilowatts for a given period. For example, the annual peak demand is the maximum demand in kilowatts that occurs within a given year; the daily peak demand is the maximum demand in kilowatts that occurs within a given day. The peak demand is usually taken for a 30 minute interval rather than an instantaneous peak.

Average Demand

Average demand is the energy divided by the number of hours for a given period. For example, if the total energy for a 30-day month is 3,600,000 kilowatt-hours, the average demand is 5,000 kilowatts (kilowatt-hours per hour).

Load Duration Curve

The load duration curve is a graph of peak demand versus duration. These curves are usually developed for a given year and they show the number of hours in a year that demand will be equaled or exceeded.

Load Factor

The load factor is the average demand divided by the peak demand for a given period. It is expressed in percentage of peak demand. For example, if the average demand for a year is 5,000 kilowatts and the annual peak demand is 10,000 kilowatts, the annual load factor is 50 percent.

Capacity Factor

Capacity factor is the term used to describe the percentage of output for a specific generating source. For example, if an electric generating plant operates at full capacity for 25 percent of the time during a year, the annual capacity factor for the plant is 25 percent.

Base Load

Base load is that portion of the load duration curve where demand is continuous or nearly continuous 100 percent of the time.

Run-Of-River Plant

A hydroelectric plant which depends chiefly on the flow of a stream as it occurs for generation, as opposed to a storage project, which has sufficient storage capacity to carry water from one season to another. Some run-of-river projects have a limited storage capacity (pondage) which permits them to regulate streamflow on a daily or weekly basis.

Spinning

The term spinning refers to the operation of a synchronous generator in a hydro plant as a condenser for the purpose of power factor correction. Normally no water is required for this procedure.

Wheeling

Wheeling is the transmission of electrical energy from the generating source to the consumer agency, normally over the transmission lines of a third party.

REGIONAL RESOURCES

General

The State of Montana's electricity supplies are provided by generating facilities owned by the Federal Government and investor-owned utilities - principally - Montana Power Company and Montana-Dakota Utilities. Montana Power Company provided in 1976 about 65 percent of the sales of electricity to ultimate consumers; however, about one-half of the total kilowatt-hours sold within State are provided by the Federal Government. The Bonneville Power Administration (BPA) markets power to an area of Montana lying generally west of the continental divide. The power is produced at federally owned hydroelectric plants within and outside of the State and sold to numerous small and medium size cooperatives organized under the Rural Electrification Act. Several large industrial users are also served directly by BPA. Many of the cooperatives also purchase power from Montana Power Company. These users along with some municipalities and irrigation projects represent potential customers for power produced at the proposed State hydroelectric projects. The United States Bureau of Reclamation is responsible for marketing power in Montana east of the continental divide. They act in a manner similar to BPA and serve many Rural Electric Associations and Cooperatives. Figure 1 indicates sales to cooperatives in 1976.

Montana Power Company

Montana Power Company supplies the majority of the communities in the western two-thirds of Montana. The maximum demand on the Company's electric system was 911,000 kw on February 4 for year 1975 with a total capability of 1,145,000 kw on that date.[1] The total installed capacity owned by the Montana Power Company in 1975 was 769,000 kw provided by 13 hydroelectric plants and two thermal generating plants located in Montana. Reliability of service is enhanced by location of hydroelectric plants on four separate watersheds with different precipitation characteristics. An additional capacity of 376,000 kilowatts was supplied by firm power purchases, exchange agreements and wheeling payments in power to meet the system demand. System electricity sales in 1976 was 6742 million kilowatt-hours, a 23.2 percent increase over 1975.[2]

Montana Power Company and Puget Sound Power and Light Company are jointly constructing a 660,000 kw mine-mouth coal-fired plant at Colstrip, Montana. The companies will have equal ownership and output from the two 330,000 kw units, and together with Washington Water Power Company, Portland General Electric Company and Pacific Power and Light Company propose to construct two additional 700,000 kw units at the Colstrip site.[3]

The Company also is participating in the proposed hydroelectric development on the Middle Snake River of a 2,700,000 kw plant at the Pleasant Valley-Mountain Sheep Project. This project is tied up in litigation and lacks congressional approvals.

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1 Prospectus: July 8, 1975, The Montana Power Company Common Stock.

2 Montana Power Company 1976 Annual Report to Shareholders.

3 Op. cit. note 1.

Bonneville Power Administration

The BPA is the marketing agent for all Federal production of power in the Northwestern United States. In 1976, the energy generated for BPA totaled 91,414 million kilowatt-hours. The source of energy was primarily from hydroelectric plants operated by the Bureau of Reclamation and Corps of Engineers, and Washington Power Supply System (Hanford Nuclear Plant) and Centralia, Washington Thermal Plant (coal-fired) and Trojan Nuclear Plant. This generation is more than 13 times the total sales of Montana Power Company in 1976.[4] In addition, through the BPA extensive transmission line network and wheeling arrangements pursuant to the Pacific Northwest Coordination Agreements, they can reach nearly every community in the Northwest. In 1976, BPA sold power in Montana to six electrical cooperatives, one Indian Affairs irrigation district, Montana Power Company and two private industries.

Energy sold by BPA in Montana during 1976 totaled about 4539 million kilowatt-hours or about 5 percent of their total production. Table II-1 was compiled from Generation and Sales Statistics for calendar year 1976 supplied by BPA.[5]

BPA Future Supply

The Pacific Northwest Utilities Conference Committee (PNUCC) has described in general the power supply position of Bonneville Power Administration in Western Montana. It stated that the regional energy supply from the public's viewpoint has changed dramatically in that western Montana will no longer enjoy an abundance of low-cost hydroelectric power. New thermal plants are being added to increase supply but the cost of building such plants is increasing at a rapid rate. The region's consumers, who are having to pay increasingly higher prices for electricity, should realize that hydroelectric resources are limited.

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[4] Op. Cit note 2, page 5.

[5] Calendar Year 1976 Generation and Sales Statistics, BPA.

Until recently BPA has been meeting the full requirements of all the public utilities in Montana. For the first time in history, BPA has informed such utilities that its resources will not be sufficient to meet their growth needs after 1983. BPA, by statute, cannot purchase or create more power generation; it can only reallocate the resources it has been authorized to market from Federal projects. In general, low cost Federal hydro power no longer is available to private utilities from BPA, and the use of new, expensive fossil fueled power plants results in a growing disparity in the cost of power between publicly-owned and privately owned utilities.

The difference in bulk power cost is reflected in significantly different rates to consumers, often between neighboring communities. This has led to proposals that existing BPA power be allocated to new public entities that would be created. Since BPA has no new resources, it could mean dividing the Federal generation into smaller shares. The result would be more uncertainity for communities now receiving BPA power, but no new power.

BPA has notified the aluminum, chemical, nickel and other basic industries which it serves directly that it cannot renew their power contracts when they expire in the mid-1980's. Currently, they face the possibility of having to close down or leave the region if they cannot obtain a future supply of power at a price they can afford. Loss of these basic industries to the Northwestern States would mean a substantial loss of jobs and production (including one-third of the country's aluminum production and all of its nickel production). The industries use a type of power that can be interrupted at a time of shortage so other consumer loads can be served. Without these industries, utilities and their consumers would have to pay more to maintain stand-by or spinning reserve. BPA cannot help solve the region's energy problems because Federal law confines the agency to its traditional role as a distributor of Federal power.

Value of Hydroelectric Power

In the calculation of the benefit-cost ratio of hydroelectric projects, the benefit, or value of capacity and energy from a hydro project is normally compared to the value of generation from a fossil-fuel plant such as, an oil-fired combined-cycle plant or gas turbine. In Montana where it appears there is adequate intermediate and low load factor hydro plants the comparison would be better if made with an investor-owned coal-fired steam electric plant. The alternative source should be capable of providing the same service and reliability with the costs adjusted or equalized accordingly. The equipment utilized in a hydroelectric power plant is considered more reliable than most other forms of generation because of its simpler design.

Irrigation demands place some restraints on the peaking ability of hydro plants. Irrigation water is released uniformly during the growing season and cannot be sent downstream or into the canals at unsteady flow rates. The uniform release during the summer months requires the hydro plant to remain in the base load of an electric utility unless an after bay reservoir is available to re-regulate peak flows. The same base load operation is necessary where a uniform release is made for recreation downstream. Such regulation might be necessary at the proposed Painted Rocks location for summer months.

VALUATION PROCEDURE

Cost of Fossil Fueled Generation

In order to determine the monetary benefit of a hydro plant, this report provides a brief analysis of the cost of producing power from a coal-fired steam electric power plant. The most significant variable in the cost of energy from a fossil-fuel generating plant is the cost of fuel. With the abundant supply of coal in the Montana area,

the cost of energy from mine-mouth generation stations will be less, due to diminished transportation costs. However, higher transmission costs of power to load centers tend to equalize this factor.

Recent contracts for coal prices are presented in Table II-2. These data shown are based on deliveries at steam electric plants during January 1977. They reflect the average cost of transportation.

The estimated cost of power from a coal-fuel generation station is presented in Table II-3. Derivation of data in Table II-3 is shown in Tables II-4 and II-5. These costs are based upon 1976 price levels with the parameters and costs taken from recent published technical data. The cost of power in terms of dollars of capacity would be about $110 and $57 per kilowatt for investor-owned and public-owned utilities respectively. The difference in cost is attributed to the fact that public-owned utilities do not pay taxes on constructed facilities and that the interest on bonds sold for construction will be tax-free resulting in lower interest rates. Furthermore, public-owned utilities do not include a rate of return on their capital investment when computing an annual investment cost.

The cost of producing energy in the comparison is largely dependent on whether the energy is produced at a mine-mouth plant or if the coal is transported some distance from the mine to the plant. As an example of the significance of the transport cost of coal, the cost of transportation in a unit train by a western utility for a distance of 300 miles is about $2.10 per ton, excluding cost of cars and loading or unloading at the plant.[6] This transportation cost would amount to an increase in energy cost of about 1 mill in the mine-mouth plant comparison.

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[6] Power Engineering, July 1977.

Basis of Comparison to Hydroelectric Power Generation

From the preceding, the benefit of hydroelectric power can be calculated. The capacity of the hydroelectric plant which can be fitted into the load curve with a high degree of reliability is dependable capacity. That amount of power can be assigned the value of capacity from a fossil-fuel plant as shown in Table II-3. When the power is integrated into a larger power network, the reliability increases in the amount of dependable capacity which can be assigned a particular plant. This report assigns a value to the dependable capacity which would need to be further verified by integrated system load and resource studies.

The energy produced by the hydroelectric project can be directly equated to the incremental cost of producing energy from a coal-fired plant which supplies power to the same network including fuel cost and variable operation and maintenance expense. The value of energy used in this report is also shown on Table II-3.

When a comparison is made to today's cost of producing power from a coal-fired generation station versus today's cost of producing power from a hydroelectric plant for which total annual costs are relatively fixed; - the comparison favors the coal-fired plant. A better analysis would be to compare the sum of the discounted annual cost streams for each alternative, assuming a value for the escalating cost of fuel as was illustrated in Chapter VII. In this manner, the inflationary rates of fuel can be compared to a plant which essentially has no inflatable cost other than labor which is normally a very small percentage of the overall costs.

Table II-1

BONNEVILLE POWER ADMINISTRATION SALES IN MONTANA[1]
During the 1976 Calendar Year

Agency	Kw	Kwh (1,000)	$
To Privately Owned Companies			
Montana Power Company	668,615	888,484	2,815,849
Anaconda Company	366,779	2,778,654	8,365,967
Stauffer Chemical Company	72,450	438,466	1,517,176
		4,105,584	12,698,992
To Cooperatives			
Flathead Electric Coop	18,840	86,114	339,818
Lincoln Electric Coop	12,600	46,353	190,177
Missoula Electric Coop	17,286	77,123	302,852
Northern Lights Electric	5,000 (E)	19,026 (E)	77,500 (E)
Ravalli Electric Coop	14,826	54,492	225,542
Vigilante Electric Coop	19,762	67,235	247,649
U.S. Bureau of Indian Affairs	28,559	82,828	354,165
		433,171	1,737,703
Totals Montana		4,538,755	14,436,695

(E) = Estimate for pro-rate between Idaho and Montana

1. Calendar year 1976 Generation and sales Statistics, BPA.

TABLE II - 2

COAL PRICES FOR

ELECTRICAL POWER GENERATION

(1977)

Montana Power Company	Quantity (1000 Tons)	¢/MM Btu	Price $/ton	Avg. Heat Rate Btu/lb.
Colstrip #1	235.0	24.2	4.15	9003 1/
Corette	50.0	28.9	4.82	8593 1/
Montana-Dakota Utility				
Lewis & Clark	29.2	61.8	8.05	6500 (E)

E = Calculated

1/ Electrical Week, McGraw Hill Pub. Co., August 1, 1977.

TABLE II-3

ESTIMATED COST OF POWER

FOR ECONOMIC COMPARISON

(1976 Prices)

Parameters Assumed	Coal-Fired Investor-Owned Utility Mine-mouth Plant	Coal-Fired Public-Owned Utility Columbia River Plant
Capital Cost ($/kw)	620 [1]	620 [1]
Economic Life (years)	35	35
Fixed Costs (%)	16.5 [2]	8.0 [3]
Fuel Heat content (BTU/ pound	9,000 [4]	9,400 [5]
Plant Heat Rate (BTU/Kwh)	10,800 [1]	10,800 [1]
Fuel Cost ($/ton)	10.00 [1]	17.00 [6]
Fuel Cost ($/million BTU)	.56	.90
Assumed Plant Size	2 - 700 MW	2 - 700 MW
Cost of Power - Capacity		
Annual Equiv. of Capital Cost ($/kw)	102.30	49.60
Annual fixed O. & M. Cost	7.50	7.75
Total	$109.80	$57.35
Cost of Power - Energy [7]		
Annual variable O. & M. (mills/Kwh)	1.5	1.5
Annual fuel cost (mills/Kwh)	4.2	7.4
SO_2 Removal (Mills/Kwh)	6.0	6.0
Total	11.7	14.9
Cost of Capacity & Energy (Assume 60% C.F.)	33 mills/Kwhr	26 mills/Kwhr

Notes

1. Future Prices of Electricity in Montana, by John W. Duffield, Jan. 1977.
2. Assume 9% interest for borrowing
3. Assumes 6½% interest for borrowing
4. Coal heat rate for Montana Plant at Colstrip, Electrical Week, Aug 1977
5. Pacific Power and Light Company prospectus, September 1975
6. Assumes $10/ton coal and 7 mills per ton-mile, utility furnish cars, for unit train, Power Engineering July 1977
7. Assumes SO_2 removal @ 6 mills per Kwhr for removal.

TABLE II - 4

METHOD USED TO ESTABLISH ANNUAL COST OF ENERGY

(Investor-Owned Utility)

1. Total Capital Cost: 1,400,000 Kw x $620/Kw = $868,000,000

2. Annual Energy Generation @ 60% Capacity Factor:

   1,400,000 Kw x 8,760 hrs/yr x .60 --- 7,358 x 10^6 Kwh

3. Annual Capital Cost for 35 yr life @ 9% borrowing ---------- 16.5%

4. Annual Costs - Capacity

   Equivalent of Capital Cost:

   $$\frac{\$868,000,000 \times .165}{1,400,000 \text{ Kw}} = \$102.30/\text{Kw}$$

   Fixed O&M:

   $$\frac{\$10,500,000}{1,400,000 \text{ Kw}} = 7.50/\text{Kw}$$

   Total $109.80/Kw

5. Annual Cost - Energy

   Capital Cost Component:

   $$\frac{\$109.80 \times 1,400,000}{7,358,000,000} = 20.9 \text{ mills/Kwh}$$

   Fuel Cost Component:

   $$\frac{\$10.00/\text{ton} \times 9,000 \text{ Btu/lb}}{2,000 \text{ lbs} \times 10,800 \text{ Kwh/Btu}} = 4.2 \text{ mills/Kwh}$$

   Variable O&M Costs: 1.5 mills/Kwh

   SO_2 removal: 6.0 mills/Kwh

   Total Annual Cost Capacity & Energy 32.6 mills/Kwh

TABLE II - 5

METHOD USED TO ESTABLISH ANNUAL COST OF ENERGY

(Publicly-Owned Utility)

1. Total Capital Cost: 1,400,000 Kw x $620/Kw = $868,000,000

2. Annual Energy Generation @ 60% Capacity Factor:

   1,400,000 Kw x 8,760 hrs/yr x .60 --- $7{,}358 \times 10^6$ Kwh

3. Annual Capital Cost for 35 yr life @ 6½% borrowing ---------- 8.0%

4. Annual Costs - Capacity

   Equivalent of Capital Cost:

   $\frac{\$868{,}000{,}000 \times .08}{1{,}400{,}000\ \text{Kw}} =$ $ 49.60/Kw

   Fixed O&M: 7.75/Kw

   Total $ 57.35/Kw

5. Annual Cost - Energy

   Capital Cost Component:

   $\frac{\$57.35 \times 1{,}400{,}000}{7{,}358{,}000{,}000} =$ 10.9 mills/Kwh

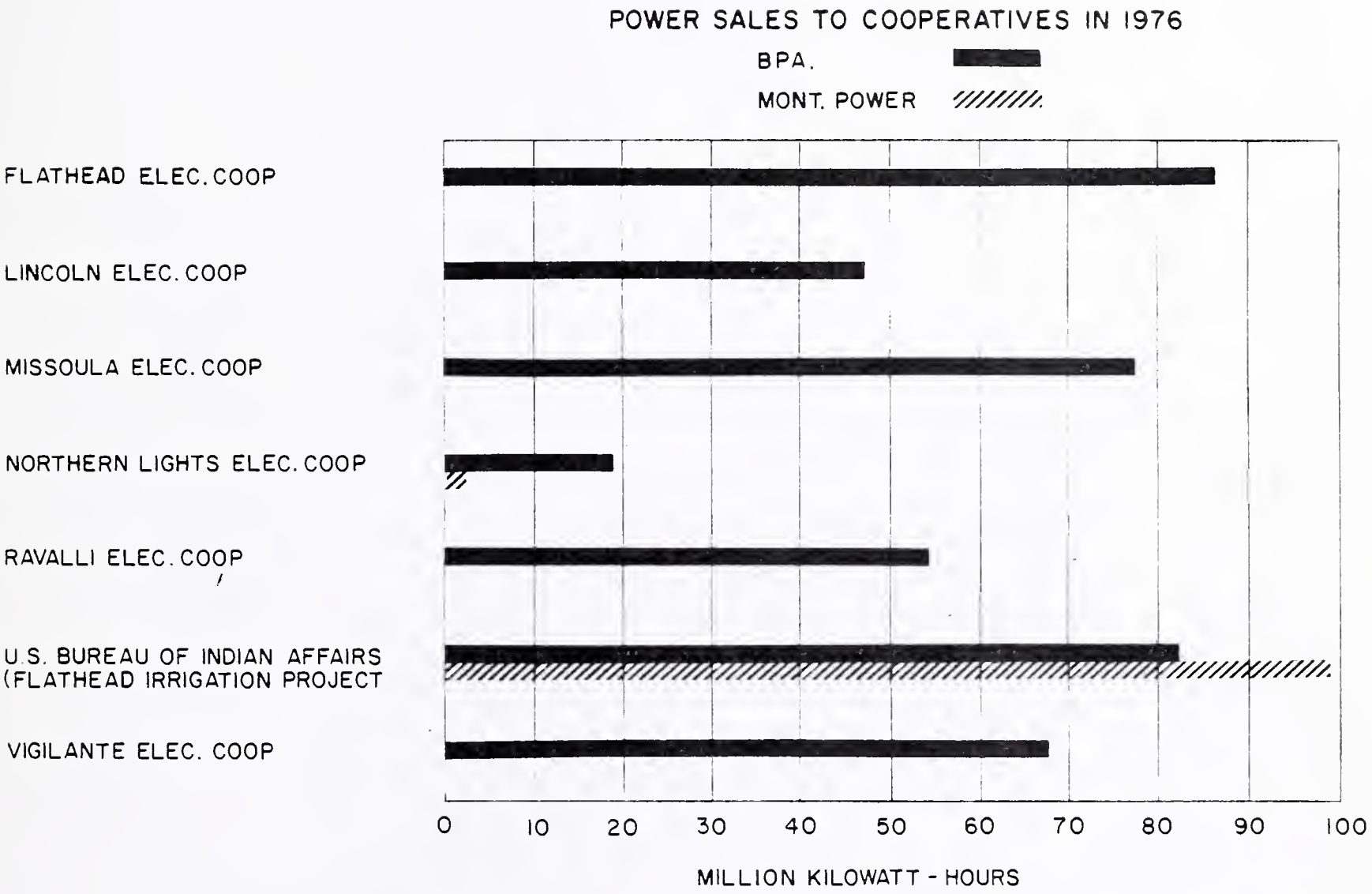
   Fuel Cost Component:

   $\frac{\$17.00/\text{ton} \times 9{,}400\ \text{Btu/lb}}{2{,}000\ \text{lbs} \times 10{,}800\ \text{Kwh/Btu}} =$ 7.4 mills/Kwh

   Variable O&M Costs: 1.5 mills/Kwh

   SO_2 removal: 6.0 mills/Kwh

Total Annual Cost Capacity & Energy 25.8 mills/Kwh



POWER SALES TO MONTANA COOPERATIVES

FIGURE 1

CHAPTER III

TURBINES AND GENERATORS

CHAPTER III
TURBINES AND GENERATORS

SELECTION OF HYDRAULIC TURBINE

Types of Turbines

Hydroelectric power plants transform the energy of falling water into electrical energy. In general, a hydroelectric power plant consists of a dam for producing the head and storage of water; an intake and penstock for conveying the water to the hydraulic turbine; the turbine itself which is coupled to a generator; and the accessory electrical equipment required to provide the power to a transmission system.

There are two basic types of hydraulic turbines: The impulse type which utilizes only the velocity energy of the water and the reaction turbine which utilizes both pressure and velocity energies. The impulse type is used for high head installations (over 1,500 feet).

Reaction wheels are classified as either mixed flow, where the water enters the wheel normal to the shaft and leaves parallel; or axial flow (tube type), where the water flow is parallel to the shaft as it passes through the wheel.

The mixed flow turbines, representing earlier development, have a turbine arrangement that uses a spiral case with gates around the periphery, called wicket gates, to control the flow. The spiral case arrangement, except in some small units, utilizes a vertical turbine axis with an elbow draft tube. This turbine is commonly called a Francis turbine which was named in honor of a hydraulic engineer who developed the turbine. This is probably the most common type of hydraulic turbine installed today. Figure 2 illustrates both the Francis turbine and the fixed blade turbine. For low heads, the turbine runner normally appears as a propeller with either fixed or movable blades. The latter provides high efficiencies for converting energy over a wider range of

heads and flows. This arrangement provides a compact turbine-generator layout but requires a complete flow passageway.

Axial flow or tube type turbines make up the second group of low head turbines. They were developed to reduce the size of the structure. The tube type turbines are almost always oriented horizontally, or nearly so. The flow approaches the turbine axially, but is given a rotating motion by guide vanes located upstream. The generators are normally located out of the waterway passage for ease of maintenance. The blades can be either fixed or movable to increase the efficiency of operation. Figure 3 shows this type of turbine. Another variation for an axial flow turbine is a bulb turbine where the flow of water flows around the generator located in a bulb and through the turbine blades. This type of turbine installation is rare in the United States.

Direct drive from the turbine to generators is normal for the vertical-shaft mixed-flow turbine. For the other types, speed increasing gears are normally utilized. The higher speed will permit a smaller, lower cost generator. The lower cost, however, is not without its penalties since there is a loss in efficiency between two and four percent when speed increasing gears are utilized, and there is an initial cost for the gear box.

The cross-flow turbine, as illustrated by the Ossberger Turbine in Figure 3, is suitable for locations where there is a wide fluctuation in the rate of flow. The Ossberger Turbine is a radial, impulse-type low speed turbine with partial admission. Water is forced through a rectangular cross-section and guide-vane system and then through blades of the runner. This flow pattern has a unique advantage of washing out refuse such as grass and leaves and melting snow and ice which may be forced between the blades of the runner as the water enters. Because of the multi-section configuration, any quantity of water from

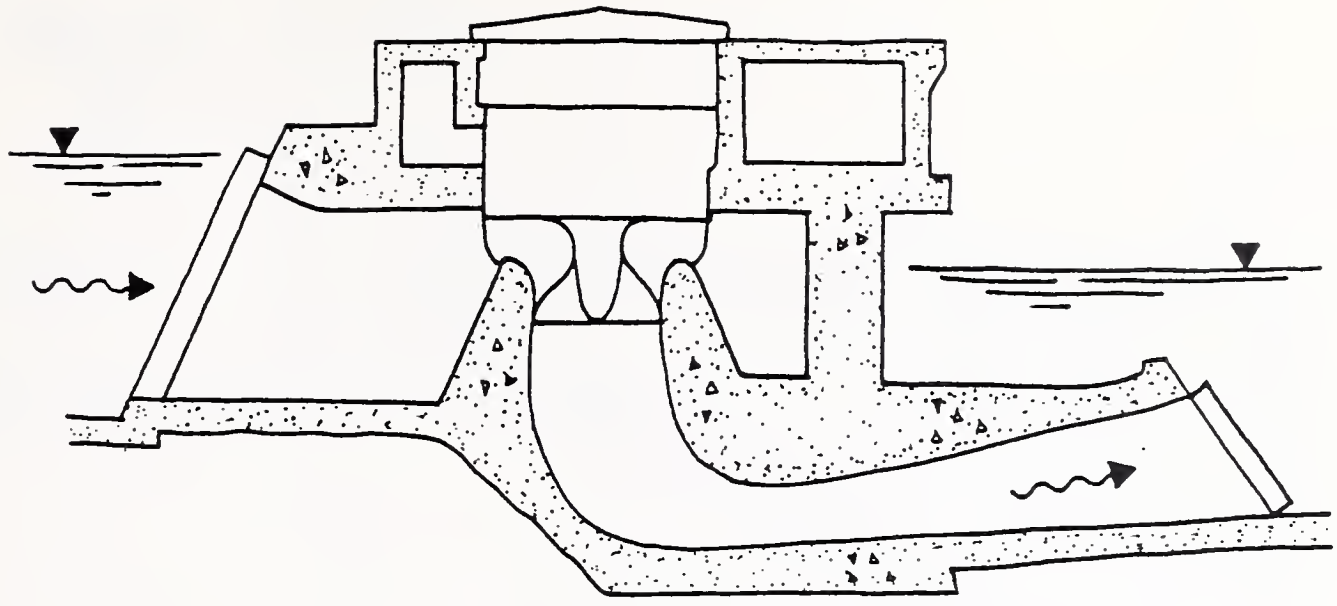
1/6 to 1/1 (16% to 100%) is usable with optimum efficiency at all ranges, allowing the turbine to accept wide fluctuations in head and flow.

Generators

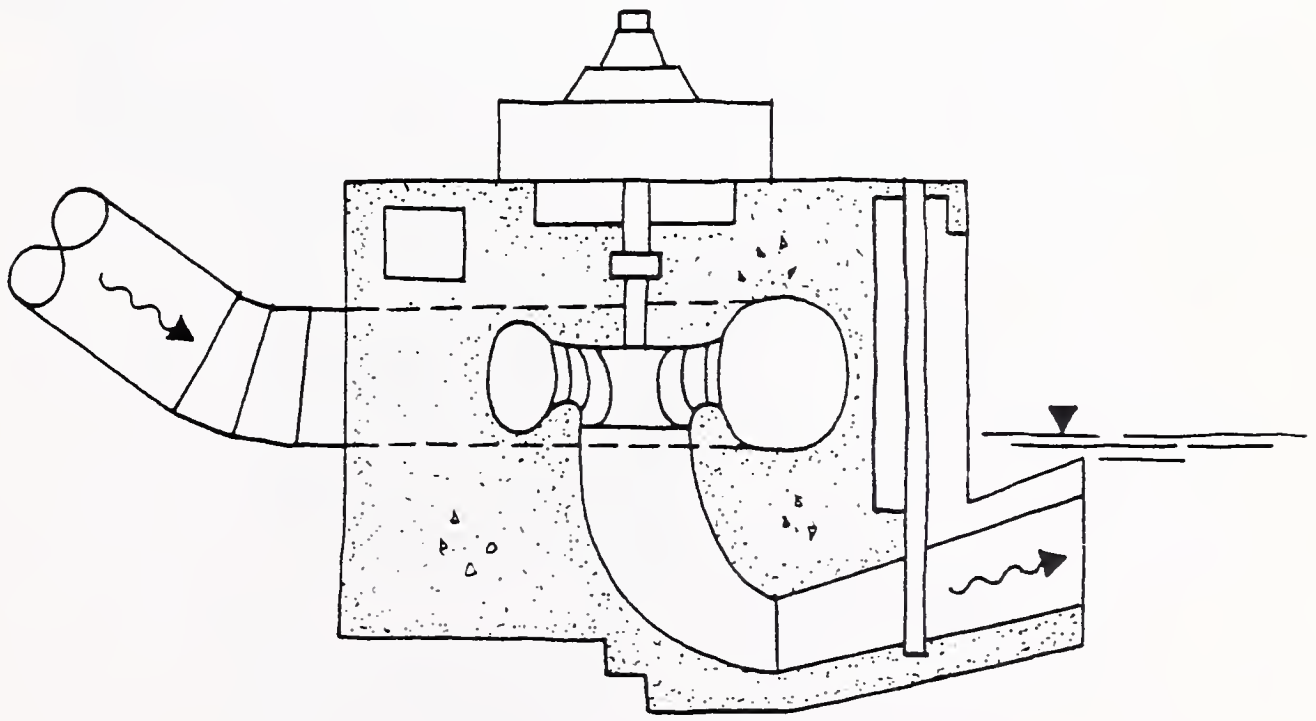
Generators can either be synchronous or induction type. Induction generators are often considered more practical for the smaller turbine-generator installations because they cost less and require less maintenance. They require no excitation and need only a squirrel-cage rotor which uses no wire windings or brushes. Furthermore, they do not run at exact synchronous speed and complex equipment is not needed to bring them on the lines. They cannot be used to establish frequency, however, and must be connected to a system with synchronous generators as they take their excitation from system current. The generators produce kilowatt-hours with a high degree of efficiency.

Synchronous generators are usually three-phase star or Y-connected machines with one end of each winding connected together in common, the other ends being used as line terminals. The alternating-current synchronous generator, or alternator, delivers its induced alternating current directly to the external circuit and is used where transmission is to be sent over long lines. The alternating current can be transformed to the approximate transmission voltage.

For the purpose of this study the generators considered for all turbine-generator installations are the more costly synchronous type because it is believed that some potential purchasers of power, or possibly the Montana Power Company who regulate the flow of power in the Montana transmission grid, may object to an induction type generator. The use of an induction type generator, if it meets the approval of all parties, should be reconsidered in final design studies.



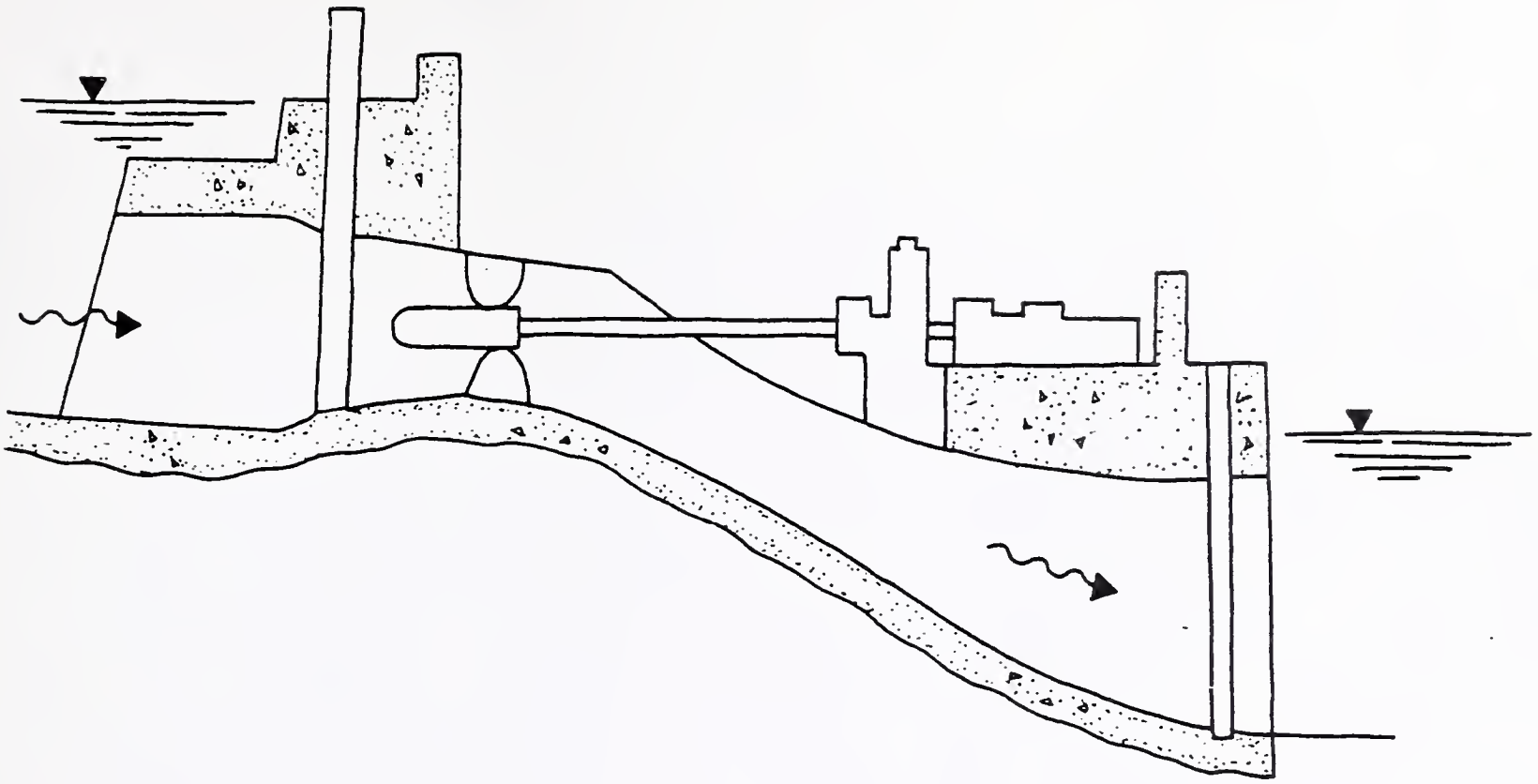
FIXED BLADE TURBINE



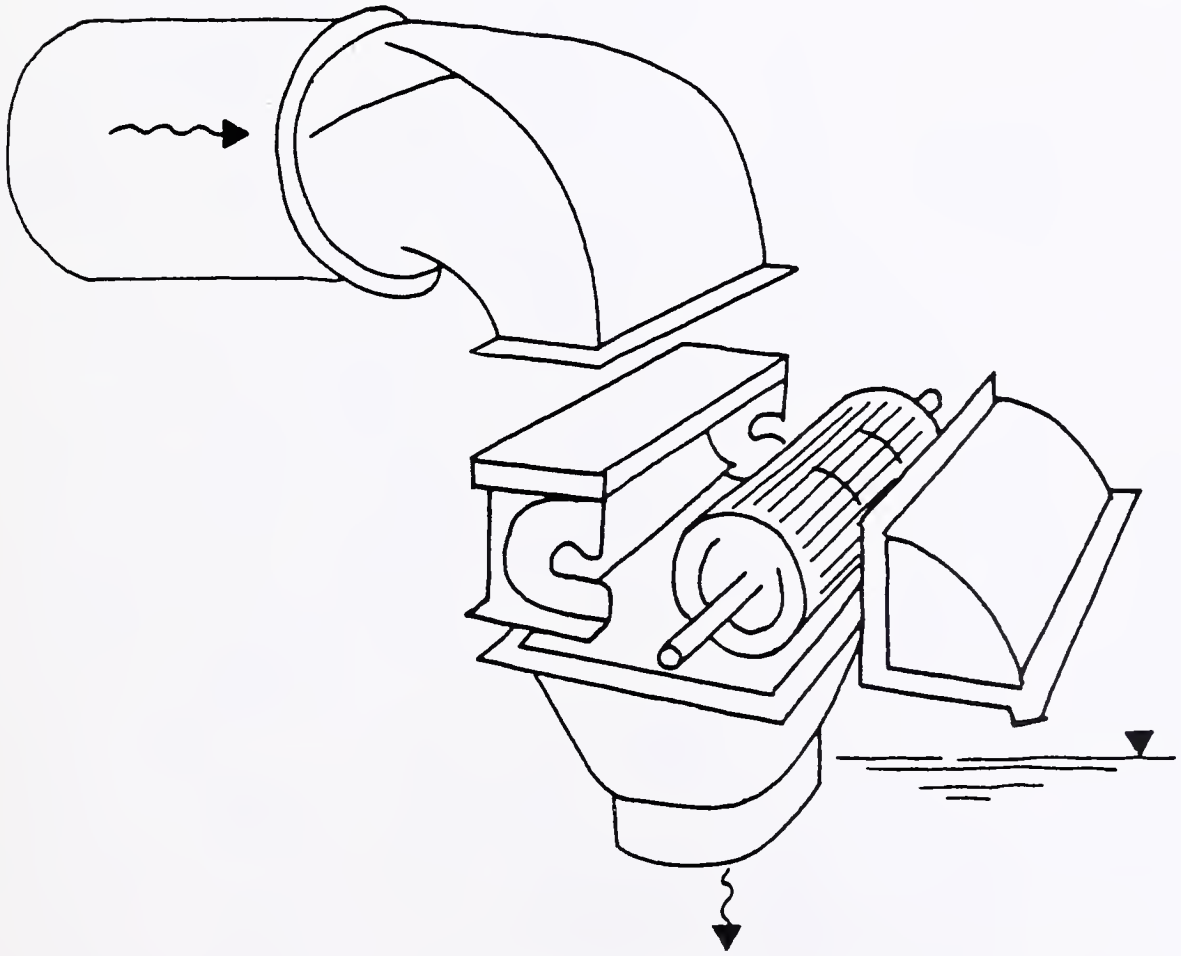
FRANCIS TURBINE

SKETCH OF FIXED BLADE
AND FRANCIS TURBINES

FIGURE
2



TUBE TURBINE



OSSBERGER TURBINE

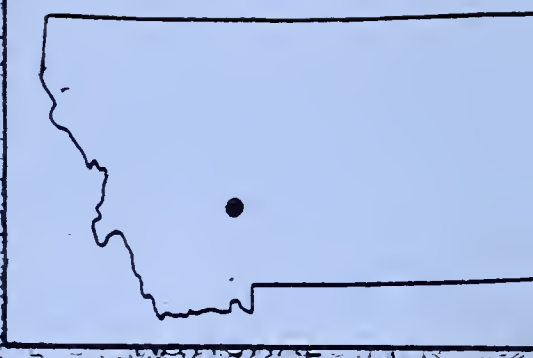
SKETCH OF TUBE TYPE
AND OSSBERGER TURBINE

FIGURE
3

CHAPTER IV

BROADWATER DAM

on
Missouri River
Broadwater County, Montana



MISSOURI RIVER

POWER PLANT

RESERVOIR

BROADWATER DAM

FOREST

Townsend

Townsend 3900

Cemetery

Water

Ranch

Racetrack

Windmill

Boston

Dry Hollow

Deep Creek Pavilion

Campground

Canyon Ferry 4000

Silos

Racetrack Mine

Iron Mask Mine

Montana Silver Star Mine

Ohio Mines

Yellowjacket

Dancy Mine

Rees Mines

Pumphouse

THE BUTTES

CEDAR HILL

CANAL

Garden Gulch

Lone Pine Gulch

Pole Gulch

High Peak

Poison Hollow

Stanton

Blacktail Divide

TABLE MOUNTAIN

SUGARLOAF MOUNTAIN

BROADWATER CO

GALL

BROADWATER COUNTY

JEFFERSON COUNTY

TIMESTONE HILLS

HORSESHOE

BASIN

7

8

2

1

0

21

22

5555

5438

5552

7637

7687

6111

5883

5838

5958

5663

5664

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CHAPTER IV
PROJECT PLAN - BROADWATER DAM

PHYSICAL DESCRIPTION OF SITE

Geographic Setting

Broadwater Dam (also known as Toston Dam) is located near the headwaters of the Missouri River, about sixteen miles north and downstream of the source of the Missouri River. The Missouri River originates at the confluence of three major rivers--the Jefferson, Madison and Gallatin Rivers--which have their sources on the eastern and northern slopes of the Continental Divide comprising the southern Bitterroot Range and Centennial Mountains. From its source near Three Forks, Montana, the Missouri flows northward through uplifted formations until it enters the broad valleys above Helena, Montana. From Helena, it flows generally north-easterly towards Great Falls and finally enters into the high plains flowing easterly into Fort Peck Reservoir and on across the northern plains.

Existing Facilities

Broadwater Dam consists of seven ogee weir sections with 54-foot bays and an irrigation canal outlet at the left abutment. The weir sections are surmounted by flashboard sections which can be extended from the top of the ogee at Elevation 3924 to Elevation 3931. The flashboards are held in place by 8-inch by 8-inch beams which provide the stop-log slots. There are nine stop-log sections to each bay.

The stop-logs are removed or installed by a fixed wheel cart traveling along the bridge deck. A small crane on the cart is used to handle the stop-logs. The flashboard support structures can be lowered into the forebay area when it is desired to remove the supports for winter ice flow. While this is a method of providing a clear and unobstructed

weir during winter, it is not a convenient method to retrieve at the end of the season in order to restore for the flashboard installations.

The main, concrete lined, irrigation canal has a capacity of 342 cfs. The flow in the canal is controlled by four 48-inch by 84-inch slide headgates with an invert elevation of 3924 feet. A separate approach channel from the river conveys water to the intake structure.

Land Ownership

The Broadwater Dam is located on State Lands and, in general, the reservoir is bounded by private lands. The Bureau of Land Management (BLM) map of Natural Resource Lands in Montana indicates a quarter, quarter section of public land, which is under BLM administration, lies adjacent to the north side of the reservoir area in the southwest corner of Section 6, T4N, R3E. There is also a quarter, quarter section in the southeast corner of Section 2, T4N, R2E that borders on the reservoir and the entire west 1/2 of NW 1/4 and SW 1/4 of Section 12, T4N, R2E is contiguous to the reservoir. A small island in Section 11, T4N, R2E, is also indicated as BLM land.

Streamflow Hydrology

On the major tributaries of the Missouri, there is some regulation of the Jefferson, Ennis Lake provides some regulation on the Madison and no significant regulation is provided by the Gallatin.

Hydrology records on the Missouri River at the site extend as far back as 1890, but are fragmented. A continuous record from 1941 to date at Broadwater Dam has been published in the USGS Water Supply papers. Partial records are available for earlier years. Records on the tributaries were obtained and correlated by means of the Corps of Engineers'

HEC-2 computer program to establish a long period of record at the Broadwater damsite. From the record compiled, potential energy available and flood characteristics were evaluated for Broadwater.

The average annual discharge for the period 1942 to 1973 was 3,735,000 acre-feet. For the reconstructed period 1926 to 1975, it is estimated that the average annual flow is 3,410,000 acre-feet. The principal gaging station for Broadwater is located about three miles below the dam near Toston, Montana. Diversions for irrigation above Broadwater serve approximately 543,000 acres.[1/]

Gaging station records used to extend the record at Broadwater were obtained through the Montana Department of Natural Resources and Conservation for the following tributary streams and locations:

USGS 06052500	Gallatin River at Logan, Montana
USGS 06043500	Gallatin River near Gallatin Gateway, Montana
USGS 06041000	Madison River below Ennis Lake, Montana
USGS 06025500	Bighole River near Melrose, Montana
USGS 06090800	Missouri River near Fort Benton, Montana

Flood Hydrology

Floods on the Missouri at Broadwater are caused by the snowmelt on the tributary streams which have their origins in the Rocky Mountain Ranges. The USGS record from 1926 to 1975 for the Missouri River at Toston, Montana indicates that the maximum discharge of record was 32,000 cubic feet per second which occurred June 6, 1948.

1/ USGS Records Sta 06054500, Missouri River at Toston

WORK PROPOSED

It is proposed that a power plant and forebay be built along the left abutment (looking downstream) and parallel to the river of the Broadwater Dam. Additionally, the intake to the main irrigation canal would be relocated at the downstream end of the power plant forebay to provide regulation for irrigation releases from the dam. New intake gates to the power forebay will be provided on the same axis as the existing dam. (See photographs, next page.)

Modifications to Existing Facilities

The existing flashboards are in deteriorated condition and require replacement at frequent intervals because of ice and debris impacting the structure. The flashboards also store water only to Elevation 3931. As an improvement to the operation of the dam and in order to increase the head on the power plant by 4 feet, it is proposed that the flashboard installations should be removed and radial lift gates installed in their place. The radial gates will permit unobstructed flow of water over the weir during flood season and also provide a means of increasing the head on the power plant by raising the operating water level to Elevation 3935 feet. With an average tailwater level at Elevation 3907, the power plant would have an average head of 28 feet on the turbines.

In order to install the radial gates and provide a support structure for the gate trunnions, it is proposed that an intermediate pier be installed in each bay with individual radial gates 24 feet wide by 12 feet in height.

The existing six foot diameter sluice gates could be plugged with concrete to increase the stability of the existing piers when the radial gates are installed. A structural analysis will be made to determine the necessity of plugging the sluices for stability when preliminary design is performed.

Proposed Power Plant Site

Upstream Control Structure

BROADWATER DAM

Power Facilities

The power plant is proposed to be located on the left abutment of the dam immediately downstream and at a right angle to the axis of the dam. The power plant will be designed as a concrete dam to resist sliding and overturning of the structure. A new power canal intake structure with an invert elevation of 3924 will be constructed at the location of the existing irrigation canal headworks. The water will flow into a basin behind the power plant; then, directed through the turbines, thereby turning the generators to produce power, and back into the river below the dam. The power plant structure can be extended downstream to accomodate as many bays of turbine-generators as may be required. The existing intake to the irrigation canal will be reconstructed at the downstream end of the power canal forebay to provide regulation for irrigation releases. The structure will be substantially the same as the existing structure with the gate sill to remain at elevation 3924. Drawing No. 1 illustrates this layout.

Selection of Units

For the given set of flow conditions and available head at the Broadwater site, it is possible to make a cost effective selection of the capacity or size of a power plant as well as the type of hydraulic turbine to be used. In regard to the Broadwater Dam installation, the selection was accomplished in steps. For the preliminary sizing, two sizes of plants were selected and operation studies run for each for the period of October 1926 through September 1975, representative of the long-term water supply, to determine the average annual power generation. The average head of the plant was assumed to be 28 feet between Elevation 3935 (one foot below the crest of the proposed radial gates), and tailwater at an average elevation of 3907 feet.

One configuration assumed using tube type turbines which are suitable for low head installation, and a second assumed vertical shaft fixed blade propeller turbines. The civil works for the propeller type turbine are more extensive and excavation for the draft tubes deeper than for the tube turbine, resulting in a high cost for this work. The efficiency range is much broader for tube turbines as indicated by Figure 4, curve A, than for fixed blade turbines, curve B. The operating characteristics of the tube turbine allowed more power to be generated over a wide range of flow rates. Drawing No. 1 shows the proposed development using six tube turbines.

Costs of furnishing turbines, generators, speed increasers (when applicable), and governors for tube turbines and vertical shaft fixed blade turbines in the range of 14 megawatt capacity are indicated in Table IV-1. From the table, it can be seen that the cost of electrical-mechanical features are about the same. Table IV-2 is a tabulation of the comparison of total capital costs of turbines, generators, accessories and civil features of the two alternative installations and of the energy that could be expected from the installations. From the table, it can be seen that the tube turbine provides slightly more kwhrs per dollar cost than the vertical shaft fixed blade turbines. Also from the table it can be seen that six units are more cost effective than seven. Tables IV-3 and IV-4 are samples of the output obtained in the computer operation studies.

TRANSMISSION

Energy will be transmitted from the project to the power purchaser's facilities by the power purchaser. It is assumed that the purchaser will arrange to transmit the power over local facilities now installed in the vicinity of the dam. The Montana Power Company has 100 Kv transmission line extending from Holter Dam near Wolf Creek to Eustis substation

at Three Forks. If the purchaser were a public agency, wheeling arrangements would be negotiated with Montana Power Company. No costs have been included herein for transmission of power.

PROJECT COSTS

Cost estimates were prepared for installation of the power plant. Costs for modification to the main dam using radial gates replacing the stop-log structures were included in the cost estimate. The restoration of the irrigation canal intake facilities was included with the cost of the new forebay structure. The cost estimate was based on using six tube-type turbine-generators in an enclosed powerhouse.

Cost estimates were prepared by computing unit quantities and assigning unit prices to the materials used in the design. The unit prices were based on recent bid prices and experience and quotations from equipment manufacturers. The cost estimate presented in Table IV-5 is based on fall 1977 price levels.

The annual cost was estimated on the basis of 40-year non-taxable revenue bonds at a 6½ percent annual interest rate. Operation, maintenance and administration were estimated at $61,300 for the power plant and related facilities.

TABLE IV-1

SUMMARY OF TURBINE AND GENERATOR COSTS

		Total Cost	KW	Cost/KW
1.	Allis-Chalmers Tube Turbines: 6 @ 2395 KW, 180 rpm with Governor; Net Head = 30 ft.	$3,500,000	14,400	
	Allis-Chalmers Synchronous Generators: 6 @ 2290 KW, 2250 Kva, 180 rpm 60 Hz, 2300 v. Including Static Excitation and Accessories	2,270,000	13,740	
		$5,770,000	13,740	$ 420
2.	Leffel Vertical-Shaft fixed blade propeller turbine, 112 rpm 2900 Hp with Governor. 6 units @ $380,800	$2,284,800	14,800	
	6 G.E. Generators, 2105 Kva 95 pf., 4160v.	2,688.000	14.000	
	6 Butterfly Valves, 102" dia. for Turbine Shutoff	900,000		
		$5,872,800	14,000	$ 420

TABLE IV-2

COMPARISON OF TYPES AND NUMBER
OF TURBINE-GENERATORS
FOR WATER SURFACE OF EL. 3935

Type	Capacity MW	Amount of Energy Generated M Kwhrs	Number of Units	Estimated Const. Cost $	Kilowatt-hours per $ Const. Cost
Tube	14.4	78.0	6	$14,693,000	5.31
Tube	16.8	80.5	7	$17,142,000	4.70
Fixed Blade	14.8	80.4	6	$15,207,000	5.29
Fixed Blade	17.2	83.0	7	$17,742,000	4.68

TABLE IV-3

POWER GENERATION

MONTANA HYDROELECTRIC DEVELOPMENT

BROADWATER RESERVOIR

1926-1975

JULY 25,1977 BY DAVE ALDEN

POWER PLANT CAPACITY = 14.4 MW

OVERLOAD FACTOR = 1.10

LOSS COEFFICIENT = 0.000000 (LOSS=KQ↑2)

GENERATOR EFFICIENCY = 0.980

TURBINE EFFICIENCY
(SIX TUBE TURBINES)

% DESIGN FLOW	EFFICIENCY
0.000	0.000
0.050	0.680
0.100	0.800
0.150	0.890
0.900	0.890
1.000	0.870
1.200	0.830

Q FOR 14.4 MW = 7123.8 CFS AT 28.0 FEET STATIC HEAD

Q FOR 15.8 MW = 8087.7 CFS AT 28.0 FEET STATIC HEAD

STATIC HEAD (FEET)

OCT	28.0
NOV	28.0
DEC	28.0
JAN	28.0
FEB	28.0
MAR	28.0
APR	28.0
MAY	28.0
JUN	28.0
JUL	28.0
AUG	28.0
SEP	28.0

TABLE IV-4

Typical Computer Calculations

Tube-type Turbine

1974

MONTH	OUTFLOW CFS	OUTFLOW AF	POWER Q CFS	SPILL AF	HEAD FT	POWER MW	ENERGY MKWH
OCT	4424.0	272025	4424.0	0	28.0	9.15	6.81
NOV	5319.0	316507	5319.0	0	28.0	11.00	7.39
DEC	4065.0	249951	4065.0	0	28.0	8.41	6.25
JAN	3624.0	222834	3624.0	0	28.0	7.49	5.40
FEB	3939.0	218764	3939.0	0	28.0	8.15	6.06
MAR	4419.0	271718	4419.0	0	28.0	9.14	6.58
APR	6932.0	412489	6932.0	0	28.0	14.10	10.49
MAY	8768.0	539131	8087.7	41831	28.0	15.84	11.78
JUN	17340.0	1031817	8087.7	550559	28.0	15.84	11.40
JUL	5276.0	324413	5276.0	0	28.0	10.91	8.12
AUG	2939.0	180715	2939.0	0	28.0	6.08	4.38
SEP	3427.0	203924	3427.0	0	28.0	7.09	5.27
						ANNUAL ENERGY	89.93

1975

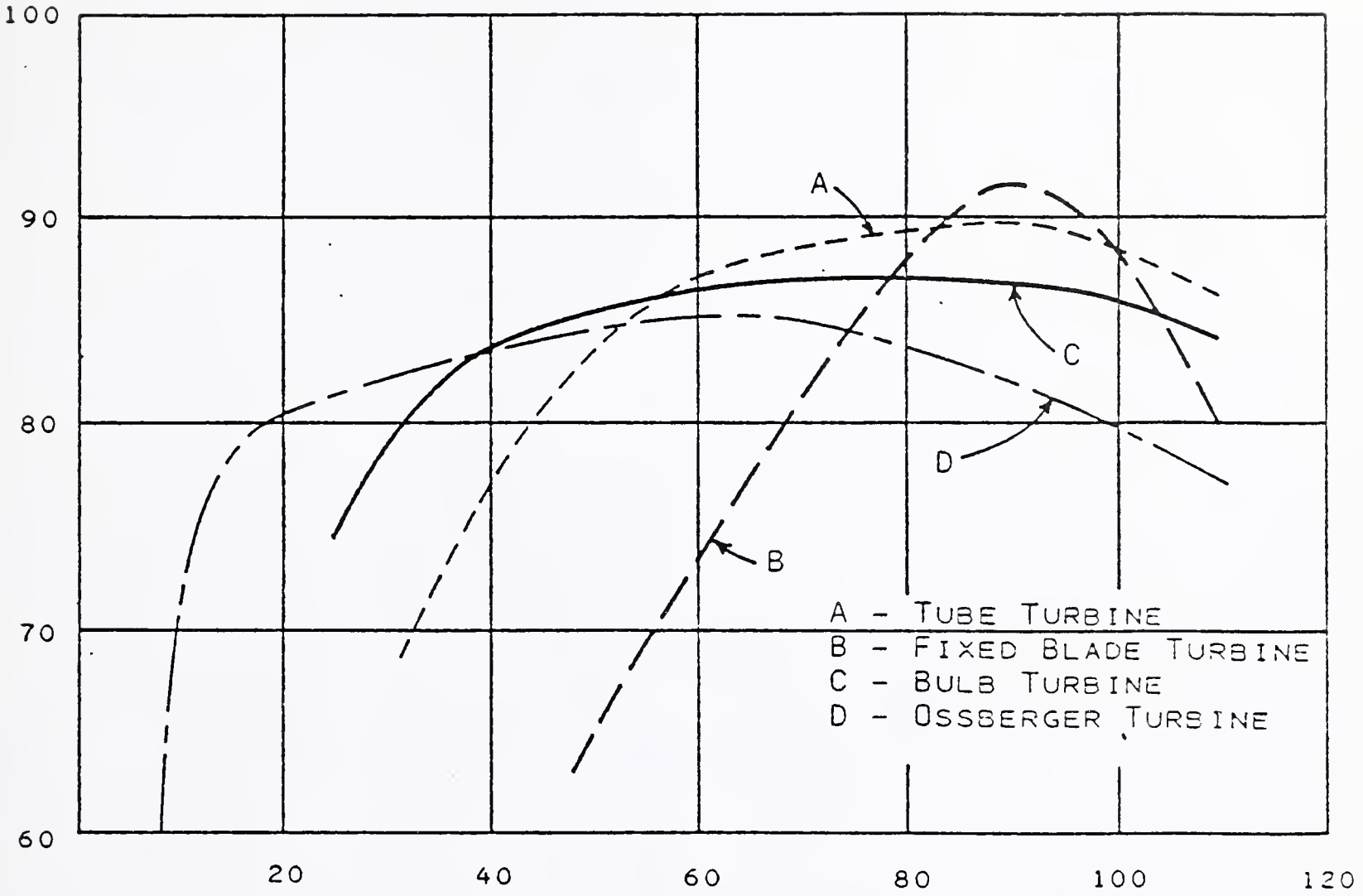
MONTH	OUTFLOW CFS	OUTFLOW AF	POWER Q CFS	SPILL AF	HEAD FT	POWER MW	ENERGY MKWH
OCT	4778.0	293792	4778.0	0	28.0	9.88	7.35
NOV	4503.0	267951	4503.0	0	28.0	9.31	6.26
DEC	4168.0	256284	4168.0	0	28.0	8.62	6.41
JAN	3395.0	208753	3395.0	0	28.0	7.02	5.05
FEB	3491.0	193883	3491.0	0	28.0	7.22	5.37
MAR	4102.0	252226	4102.0	0	28.0	8.48	6.11
APR	4892.0	291098	4892.0	0	28.0	10.12	7.53
MAY	10090.0	620419	8087.7	123119	28.0	15.84	11.78
JUN	19550.0	1163323	8087.7	682065	28.0	15.84	11.40
JUL	14240.0	875596	8087.7	378296	28.0	15.84	11.78
AUG	5729.0	352268	5729.0	0	28.0	11.85	8.58
SEP	4750.0	282649	4750.0	0	28.0	9.82	7.31
						ANNUAL ENERGY	94.89

AVERAGE ANNUAL ENERGY 77.98

TABLE IV-5

BROADWATER PROJECT COSTS

Feature - Power Plant	Costs
Mobilization and Care of River	$1,220,000
Modifications to Dam	811,000
Remove Existing Walls	35,000
Construct Forebay (Incl. Gates)	1,264,000
Turbine - Generators (6 Tube Type) (2400 kilowatts each)	5,770,000
Accessory Electrical Equipment	1,093,000
Miscellaneous Power Plant Equipment	138,000
Roads and Bridges	40,000
Switchyard	50,000
Sub-total	$10,421,000
Indirects and Overheads	
Contingencies 20%	2,084,000
Engineering, Administration & Legal 15%	1,563,000
Interest During Construction and Investment Credit 6%	625,000
TOTAL PROJECT COST - FALL 1977	$14,693,000
Annual Costs	
Annual Carrying Charges for Bond Retirement (Debt Service 40 yrs. @ 6½%)	1,038,700
Annual Operation, Maintenance & Administration	61,300
Total Annual Cost	$1,100,000



NOTE: GENERATOR AND PLANT LOSSES - ASSUME 98%
GEAR SET LOSSES - ASSUME 96% (WHERE APPLICABLE)

PERFORMANCE CURVES FOR SELECTION
OF HYDRAULIC TURBINES

FIGURE
4

CHAPTER V

DEADMAN'S BASIN

at
Musselshell River
Wheatland County, Montana

RESERVOIR

DEADMAN'S BASIN DAM

POWER PLANT

MUSSELSHELL RIVER

Oxford Siding

Nihill Siding

Windmill

Windmills

Mailum Siding

Abandoned

Ringate

Burgoyne Siding

Ashley Coulee

Coulee

Wallers

WHEATLAND COUNTY

GOLDEN VALLEY COUNTY

CHICAGO MILWAUKEE ST. PAUL AND PACIFIC

GREAT NORTHERN

Minneapolis

STILLWATER

YELLOWSTONE

GOLDEN VALLEY COUNTY

MUSSELSHELL COUNTY

GRASS COUNTY

CAYUSE HILLS

DEADMAN'S BASIN
PROPOSED POWER PLANT

0 5 MILES

CHAPTER V

PROJECT PLAN - DEADMAN'S BASIN

PHYSICAL DESCRIPTION OF SITE

Geographic Setting

The Deadman's Basin Project is located in Wheatland County about 20 miles east of Harlowton, Montana. Water diverted from the Musselshell River by means of a 11.5 mile supply canal is conveyed to an off-stream storage reservoir which lies some 160 feet higher in elevation than the river and less than a mile north of the stream. The water released from the dam through the outlet structure is diverted in an open channel to an afterbay pond which supplies two irrigation canals. The Barber Canal returns water to the Musselshell River near Barber with minor irrigation supplied near the river. The Careless Creek Canal diverts water from the afterbay for a distance of 7 miles and empties into the natural channel of Careless Creek, which then flows in the meandering stream course to join the main river about 5 miles east of Ryegate.

Exisiting Facilities

The Deadman's Basin Project consists of a reservoir which yields, according to the report prepared by the Montana Department of Natural Resources and Conservation[1/], a firm annual amount of 34,000 acre-feet. An irrigation canal system is also included in the site facilities.

Land Ownership

All of the area required for the proposed development for the power plant, penstock, and turbine would lie within State-owned lands. The penstock and power plant

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1/ "State Water Conservation Projects", March 1977, by Water Resources Division, Montana DNRC.

facilities will be located within Section 36, T7N, R18E which is a designated school lands section. Negotiations for use of the required area for the plant would be conducted with the Montana Department of State Lands.

Stream Hydrology

Continuous records of the Musselshell River at Ryegate were obtained from 1946 to 1973. Additional records at Roundup, downstream, and at Harlowton, upstream, as well as So. Fork Musselshell near Martinsdale and the Musselshell River at Musselshell were obtained from USGS records. The total reconstructed inflow to Deadman's Basin would be approximately equivalent to the historical release to Careless Creek plus the Musselshell River flow at Ryegate, but limited by the capacity of the supply canal. A more detailed hydrological study will be made during the preliminary design studies to evaluate the usable power releases after irrigation demands have been satisfied by the diversions from the supply canal and minor irrigation uses from the Barber Canal.

Flood Hydrology

The flood potential at the Deadman's Basin is minimal because the major water supply is by means of the supply canal which has a capacity of 600 cfs at the intake. The reservoir basin lies on a plateau with contribution from local runoff practically non-existant. Only rainfall or precipitation on the lake surface itself, comprising some 2,100 surface acres, plus an estimated 500-600 acres on surrounding area would produce any storm runoff. The outlet conduit with a capacity of 1,000 cfs and the 30-foot spillway could handle any conceivable flood flow.

WORK PROPOSED

Of the 34,000 acre-feet of annual yield at the reservoir, 25,600 acre-feet of water have been contracted for by users in the area. Consequently, a moratorium on water sales from Deadman's Basin has been in effect since 1973. High losses in the irrigation canal systems and salt accumulation and ground saturation of many acres around the afterbay have made it necessary to find an alternate method for returning water to the river. It is proposed that the building of an intake structure, penstock and powerhouse at the project to carry irrigation water from the offstream storage reservoir directly to the river, opposite the reservoir, would accomplish this purpose without affecting the irrigation system operation, as well as providing an energy source for the area. (See photograph, next page.)

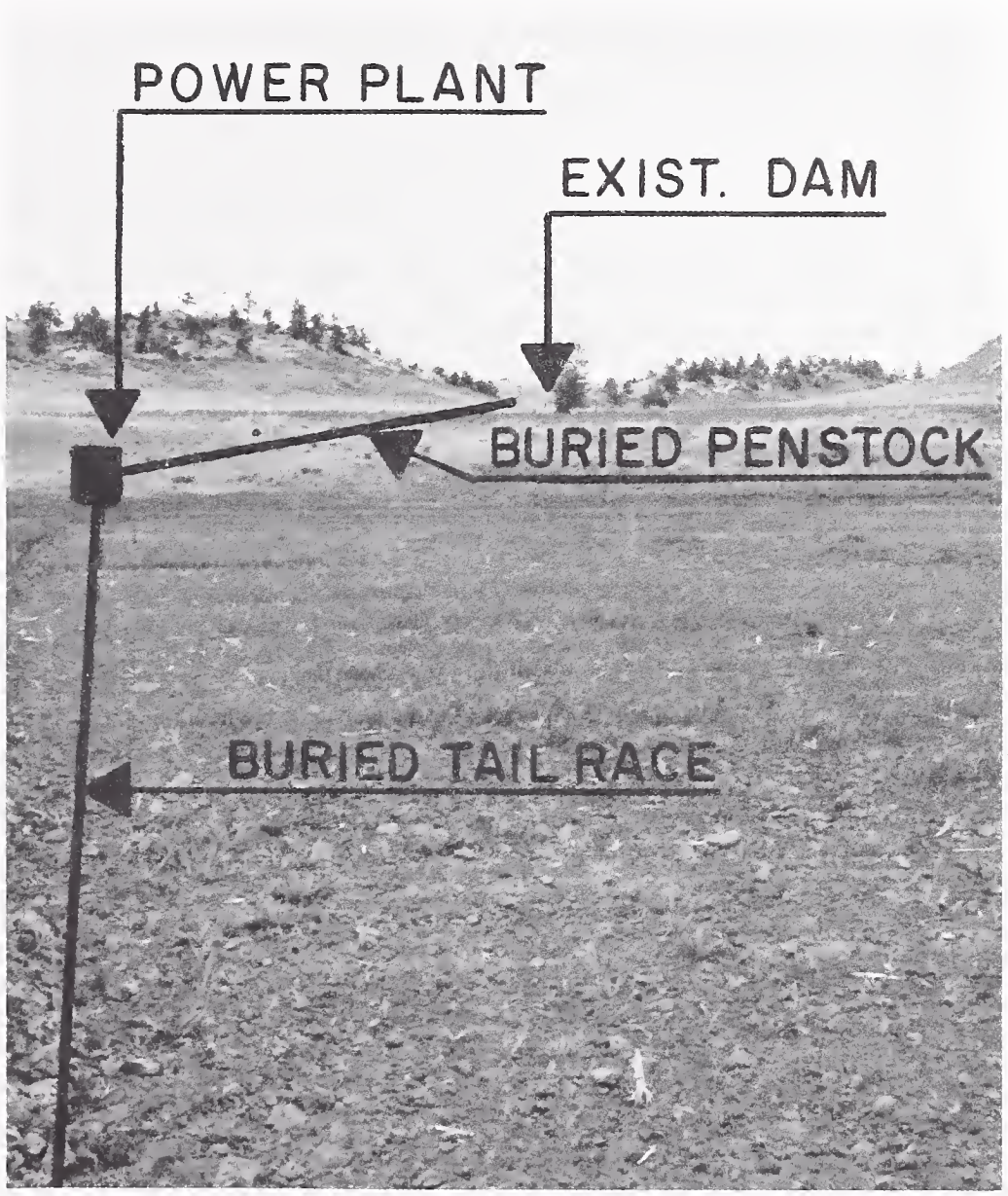
Modifications to Existing Facilities

The existing intake to the supply canal can divert all flows in the river up to when the diversion dam is overtopped. Further studies will determine methods to improve the intake condition.

The control structure north of the highway is a constricting point. In order to prevent ice plugs from forming in the gate structure, it may be desirable to remove the gate structure and open the channel for installation of radial gates or to relocate the intake facility on the river side of the railroad track. The existing concrete intake structure would serve to supply the canal water if trash racks were reinstalled.

Power Facilities

The proposed penstock to carry water to the power plant will be located at the saddle dike on the south side of



Proposed Power Plant Location

DEADMAN'S BASIN

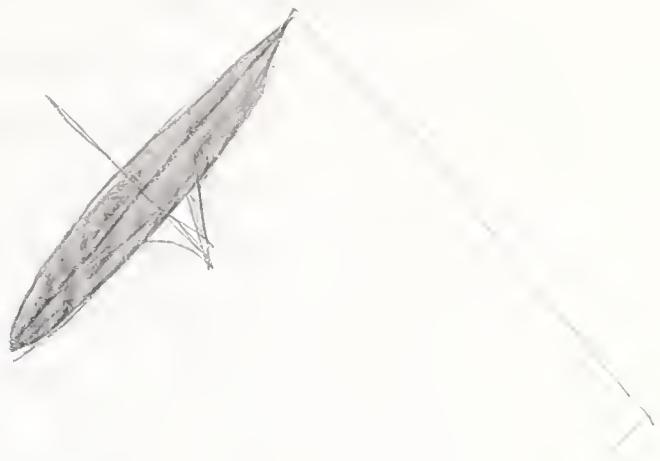
the Deadman's Basin. It will be excavated into the dike and extended into the reservoir area to an intake structure which would permit withdrawing water to a minimum level of 3898 feet.

This level would provide sufficient head over the intake invert (Elevation 3886 feet) to prevent air entrainment in the penstock. The operating level of the reservoir would range from 30,000 acre-feet minimum storage to full capacity at 76,900 acre-feet. This would provide 46,900 acre-feet annual active storage with a reserve minimum pool for irrigation use in an extremely dry year.

The penstock selected is a 84-inch steel diameter pipe entirely buried except for the short section midway down the pipeline where it crosses a rock outcrop. The penstock will be vented near the crest of the dike and contain a high level control valve to permit draining the pipe (if required) or to perform maintenance on the penstock.

The intake tower for the power plant will be located about 600 feet away from the crest of the auxiliary dike at the south side of the lake. The structure will be similar to the existing facility at the outlet of the main dam and have trash bars to prevent debris entering the penstock line. The intake will be connected to the penstock by means of a buried concrete pipe extending from the reservoir to the landward side of the dike.

The tailrace extending from the power plant to the river would be covered conduit or concrete pipe to convey the discharge from the power turbine units to the river. The conduit system would be buried to equivalent level of the river channel to permit the pipes to pass under the highway and railroad embankments. The outlet structure will consist of a concrete discharge structure to prevent erosion of the railroad embankment and river encroachment on the left bank of the stream.



The power plant will be located about 400 feet north of U.S. Highway No. 12 near a rock ledge bench which appears to be the antecedent streambed of the Musselshell River. The structure will be constructed of reinforced concrete with full enclosure of the units to protect the equipment from the weather. The draft tubes from the turbine would discharge into the pits below the powerhouse floor and water would be conveyed to the river through the tailrace closed conduit. Drawing No. 2 shows the conceptual design for the power plant facilities.

Selection of Units

For the type of service required at this site a conventional Francis turbine or cross-flow (Ossberger) turbine could be considered. See Figure 4 at the end of Chapter III, curve D, for typical efficiency ranges of the Ossberger turbine. The efficiency curve for a Francis turbine will look similar to curve B, Figure 4. The Ossberger turbine seems more suitable for the installation because it has a wide efficiency range for varying flow conditions and can tolerate head fluctuations due to seasonal water levels in the storage reservoir. Because of the limited amount of hydrology data, it did not appear necessary to compare the energy generation between the two types of turbines.

A simulated power plant operation was performed on a typical average year to estimate the reservoir levels for power withdrawals combined with irrigation demands. The average head was used in the computer studies decribed in the next paragraph. Table V-1 tabulates results of the simulated operation inflows for water year 1970-71. That water year appeared to be fairly close to average runoff at the intake to the supply canal. A normal storage level of 60,000 acre-feet beginning October lst was assumed to provide as much head on the plant as reasonably possible and to provide

almost 5,000 acre-feet per month releases from the reservoir for power purposes until spring runoff began. A minimum storage level at 30,000 acre-feet was selected as a target storage level desirable to meet by April 1st.

In order to determine long-term annual energy production at the site, a simulated operation study, for a period of 40 years of reconstructed flow at the supply canal intake was performed by computer. The inflow to Deadman's Basin, as reconstructed at the supply canal intake, using the correlation between Musselshell River at Harlowton and the record at Ryegate with estimated irrigation values added, provided the long-term record. The simulated annual operation provided an average head of 148 feet. Also considered was a constant rate of irrigation depletion (7500 acre-feet per year) and fish and wildlife releases (3700 acre-feet per year) at the diversion dam. These depletions were assumed to be lost for power generation.

Three sizes were considered for the power plant installation: 1300 kilowatts, 2600 kilowatts and 3900 kilowatts. Six computer runs were made for the 40-year period. The average generation is tabulated in Table V-2. Samples of computer data supplied to the programs and a typical final year and average generation total are given in Tables V-3 and V-4. The installation with 2600 kilowatts was selected as the most economical.

PROJECT COSTS

Cost estimates were prepared for a powerhouse, penstock and intake with the power plant located north of Highway 12 where there is apparently suitable foundation for the powerhouse. The project was estimated on the basis on two Ossberger-type turbines installed in an enclosed powerhouse for weather protection.

The cost estimate was prepared by computing unit

quantities and assigning unit prices to materials used in the design. The unit prices were based on recent bid prices and average costs for similar type construction. Table V-5 is a summary of project costs and estimated annual cost based on a 40-year bond retirement at six and one-half percent annual interest rate.

TABLE V-1

ASSUMED OPERATION OF DEADMAN'S BASIN
IN TYPICAL AVERAGE WATER YEAR

(UNITS IN ACRE FEET EXCEPT AS NOTED)

	Mussel Shell River Above Shawmut (A)	Spill at Diversion Dam (B)	Diversion To Supply Canal	(Historical) Depletion For Irrigation (C)	Net Supply Deadman's Basin	Storage on First of Month	Reservoir Elevation (Feet)	Static Head (Feet) (D)	Proposed Irrigation Release (E)	Releases for Power	Generation $\overline{M}$ Kwh (F)	Capacity Factor (Monthly) (G)
1970 OCT	3,100	50	3,050	0	3,050	60,000	3,912.5	156.5	0	8,050	1.01	.52
NOV	2,300	0	2,300	0	2,300	55,000	3,910.0	154	0	7,300	0.91	.49
DEC	2,300	0	2,300	0	2,300	50,000	3,907.0	151	0	7,300	0.91	.47
1971 JAN	1,800	0	1,800	0	1,800	45,000	3,904.0	148	0	11,800	1.48	.77
FEB	12,100	0	12,100	0	12,100	35,000	3,898.0	142	0	11,100	1.39	.80
MAR	6,600	50	6,550	0	6,550	36,000	3,898.5	142.5	0	11,550	1.44	.74
APR	18,100	600	17,500	–	17,500	31,000	3,895.5	139.5	500	12,000	1.50	.83
MAY	32,100	600	31,500	990	30,510	36,000	3,898.5	142.5	1,000	12,000	1.50	.78
JUN	23,300	600	22,700	1,180	21,520	53,510	3,909.0	153	2,000	11,030	1.38	.76
JUL	13,900	600	13,300	1,660	11,640	62,000	3,913.5	157.5	1,500	7,140	0.89	.46
AUG	8,300	600	7,700	2,100	5,600	65,000	3,915.0	159.0	1,500	7,300	0.76	.39
SEP	9,300	600	8,700	100	8,600	61,800	3.913.5	157.5	500	9,900	0.64	.35
	133,200	3,700	129,500	6,030	123,470				7,000	116,470	14.56	.64
OCT						60,000						

(A) Assumed Reconstructed flow at Deadman's Basin Supply Canal

(B) Release for local use and unavoidable spill

(C) Historical

(D) Normal Tailwater Elevation assumed 3,756 feet

(E) Assumed Irrigation Demand Barber

(F) Factor = L25 Kwh per acre foot based on L48' mean head

(G) 2,600 KW installed capacity

TABLE V-2

DEADMAN'S BASIN, MONTANA

Generation vs. Installed Capacity

Installed Capacity KW	No. of Units	Design Flow cfs	Average Annual Generation $\bar{M}$ Kwh	Estimated Capital Cost of Installation	Kilowatt-hours per $ Investment
1300	1	133	7.2	$ 2,800,000	2.57
2600	2	275	10.3	$ 3,636,000	2.83
3900	3	436	11.7	$ 5,300,000	2.21

TABLE V-3

POWER GENERATION

MONTANA HYDROELECTRIC DEVELOPMENT

DEADMAN'S BASIN

1934-1973 (RECONSTRUCTED RECORD)

AUGUST 2,1977 BY DAVE ALDEN

POWER PLANT CAPACITY = 2.6 MW

OVERLOAD FACTOR = 1.10

LOSS COEFFICIENT = 0.000070 (LOSS=KQ↑2)

GENERATOR EFFICIENCY = 0.980

TURBINE EFFICIENCY
(TWO OSSBERGER TURBINES)

% DESIGN FLOW	EFFICIENCY
0.000	0.000
0.020	0.000
0.021	0.855
0.630	0.855
0.800	0.840
1.000	0.800
1.200	0.750

Q FOR 2.6 MW = 274.4 CFS AT 148.0 FEET STATIC HEAD

Q FOR 2.9 MW = 325.2 CFS AT 148.0 FEET STATIC HEAD

STATIC HEAD (FEET)

OCT	148.0
NOV	148.0
DEC	148.0
JAN	148.0
FEB	148.0
MAR	148.0
APR	148.0
MAY	148.0
JUN	148.0
JUL	148.0
AUG	148.0
SEP	148.0

DEADMAN'S BASIN

TABLE V-4

Typical Computer Calculations

1973

MONTH	OUTFLOW CFS	OUTFLOW AF	POWER Q CFS	SPILL AF	HEAD FT	POWER MW	ENERGY MKWH
OCT	122.0	7500	122.0	0	147.0	1.27	0.95
NOV	35.3	2100	35.3	0	147.9	0.37	0.25
DEC	9.8	600	9.8	0	148.0	0.10	0.08
JAN	14.6	900	14.6	0	148.0	0.15	0.11
FEB	28.8	1600	28.8	0	147.9	0.30	0.22
MAR	49.6	3050	49.6	0	147.8	0.52	0.37
APR	111.8	6650	111.8	0	147.1	1.17	0.87
MAY	63.4	3900	63.4	0	147.7	0.66	0.49
JUN	107.6	6400	107.6	0	147.2	1.12	0.81
JUL	47.2	2900	47.2	0	147.8	0.49	0.37
AUG	0.0	0	0.0	0	148.0	0.00	0.00
SEP	68.9	4100	68.9	0	147.7	0.72	0.54
						ANNUAL ENERGY	5.06
						AVERAGE ANNUAL ENERGY	10.37

TABLE V-5

DEADMAN'S BASIN

PROJECT COSTS

Feature - Intake and Penstock	Costs
Intake Structure	$ 50,000
Upper Slide Gates & Controls	$ 175,000
Intake Pipe (Installed)	$ 431,000
Steel Penstock Pipe (2600 ft.)	$ 558,000
Penstock Excavation & Cover	$ 121,800
Supply Canal Improvements	$ 20,000
Sub-total	$ 1,353,800

Feature - Power Plant	
Powerhouse Enclosure	$ 70,000
Ossberger Turbines/Generator 2 Units @ 1300 kw	$ 646,700
Electrical Accessory Equipment	$ 225,000
Miscellaneous Electrical Facilities	$ 75,000
Sub-total	$ 1,016,600

Feature - Tailrace and Discharge Structures	
Conduit to River	$ 100,000
Outlet Structure	$ 50,000
Excavation and Backfill	$ 58,600
Sub-total	$ 208,600
TOTAL DIRECT COST	$ 2,579,000

Indirects and Overheads	
Contingencies 20%	$ 515,800
Engineering Administration & Legal 15%	$ 386,900
Interest During Construction 6%	$ 154,300
TOTAL PROJECT COST	$ 3,636,000

TABLE V-5 (Cont)

Annual Cost

Debt Service (40 yrs. @ 6½%)	$ 257,000
Annual Operation, Maintenance & Administration	$ 25,000
TOTAL ANNUAL COST	$ 282,000

CHAPTER VI

PAINTED ROCKS DAM

on
West Fork Bitterroot River
Ravalli County, Montana

WEST FORK
BITTERROOT RIVER

POWER PLANT

PAINTED ROCKS DAM

RESERVOIR

BITTERROOT NATIONAL FOREST

BITTERROOT RANGE

BITTERROOT MOUNTAINS

RAVALLI CO

IDAHO CO

LEMHI CO

MONTANA

IDAHO

BASE LINE

PAINTED ROCKS DAM
PROPOSED POWER PLANT

0 5 MILES

CHAPTER VI
PROJECT PLAN - PAINTED ROCKS

PHYSICAL DESCRIPTION OF SITE

Geographic Setting

The Painted Rocks Dam is located in southwestern Montana on the West Fork of the Bitterroot River, about 90 miles south of Missoula, Montana. The location is in a mountainous area of the Bitterroot Range and provides a means of regulating the snowmelt runoff through the Bitterroot River Valley where numerous farms and several small communities are located ranging in size from a few hundred to 30,000 population at Missoula.

Existing Facilities

Painted Rocks Dam impounds about 32,400 acre-feet storage at an elevation of 4,500 feet. Water is released primarily for fish and wildlife, of which 5,000 acre-feet of water is purchased by the Department of Fish and Game. Painted Rocks Lake is a highly desirable recreation area for vacationers and fishermen. An intake structure, spillway, control gates, counterfort wall, and conduit system complete the facilities found at the damsite.

Land Ownership

The major portion of the Painted Rocks reservoir and dam is under State of Montana ownership. Much of the land was acquired by a special use permit from the U.S. Forest Service. The project is near the Bitterroot Wilderness Area.

Streamflow Hydrology

The runoff from the high ridges surrounding the West Fork of the Bitterroot River is principally from snowmelt.

The USGS Gaging Station, West Fork Bitterroot River near Conner, Montana, is located about a mile downstream from the Painted Rocks Dam. Records are available from 1940 to 1975 on a continuous basis. Some intermittent records are available for a station near Darby. However, this record includes runoff from 572 square miles of drainage area; whereas the Conner Station is for runoff from 317 square miles. The average annual runoff of West Fork Bitterroot River near Conner for the 35 years of record is 207,700 acre-feet.

Flood Hydrology

The runoff from the high ridges surrounding the West Fork of the Bitterroot River is principally from snowmelt. The USGS Gaging Station indicates that the maximum flood of record from 1941 to 1975 has not exceeded 4060 cfs. However, this represents the regulated outflow from the reservoir. The record flood occurred in May 1947, which indicates that it was a snowmelt flood. No winter rain floods have approached the magnitude of the snowmelt floods. The powerhouse will be protected by the existing counterfort wall along the spillway stilling basin and will not be subject to flooding from backwater in the river.

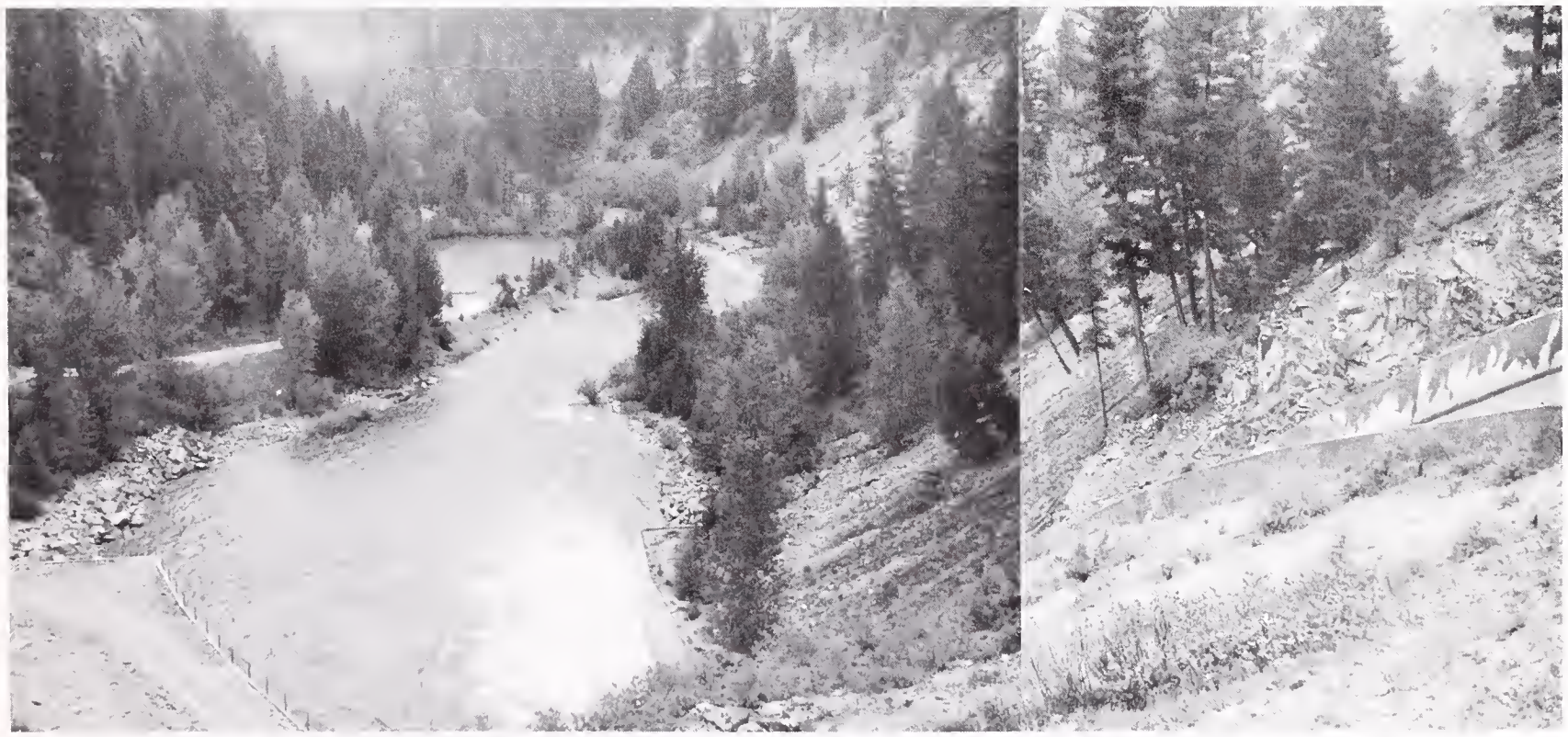
WORK PROPOSED

It is proposed that a power plant be built near the toe of the existing spillway on the left bank of the spillway structure. In addition, a steel penstock will be installed in the 10-foot conduit from the existing gate structure to a point near the portal of the existing tunnel outlet to carry water to the turbines in the power plant. A control valve will be installed at the portal of the tunnel so that reservoir releases can be made when the power plant is not operating. (See photographs, next page.)

Proposed Power Plant Location
Adjacent to Spillway

PAINTED ROCKS

Powerhouse Site



Spillway Stilling Basin

Modifications to Existing Facilities

No modification will be necessary at the intake structure or control gates. The existing outlet conduit between the outlet gates and the discharge point in the spillway will be used for the new penstock tunnel. A bypass valve will be installed at the lower end of the tunnel to permit releasing water through the dam in the event that the power plant is not in service. The existing counterfort wall on the left spillway channel will be utilized to minimize the cost of the power plant structure, but will be modified to permit discharge of the turbine outflow through wall openings into the river.

Power Plant Facilities

The site selected for the power plant permits utilization of the existing conduit system and provides for an area in which to construct the plant at the toe of the dam. Drawing No. 3 indicates the relative location of the proposed plant to the existing facilities.

The 78-inch diameter steel penstock will be installed in the 10-foot conduit from the existing gate structure to a point about 100 feet from the mouth of the existing tunnel outlet. At that point, a bifurcation will be installed with the left leg turning about 30 degrees away from the center line of the conduit and providing the main header for the power penstocks. The right leg will continue to the mouth of the tunnel with a sleeve valve installed near the bifurcation point. The conduit will be warmed by the existing ventilation ducts which will be connected to the turbine generator room for supplying warm air to the sleeve valve. This arrangement will permit the sleeve valve to be used in winter months for bypassing water directly into the spillway stilling basin without building up ice. Under normal conditions the turbine water discharge will occur through the counterfort wall and no adverse freezing is foreseen.

Selection of Units

A series of reservoir operation studies were made to determine the average annual energy that could be generated at the Painted Rock Dam. The representative water supply period for the historical record of releases below the dam was used for estimating energy generation. The average monthly flows for West Fork Bitterroot River at Conner from 1942 to 1973, inclusive, were routed through the reservoir using a storage rule curve for reservoir levels of the historical record. In general, the reservoir elevation for specific months each year was assumed to be the same elevation as storage maintained at 10,000 acre-feet minimum level from the first of December to the end of May and increased to full reservoir level until the end of August. The storage level was then reduced through September, October and November to the minimum level.

For the power plant, a Francis turbine or cross-flow (Ossberger-type) turbine could be used. They are shown on Figures 2 & 3, Chapter 3. The efficiency curves versus percent of flow for various turbines are provided in Figure 4. The turbine characteristics of a Francis wheel are similar to those for Turbine B shown on the chart.

The reservoir is in a mountainous area and receives heavy runoff in the spring and summer months from snowmelt and low flows during the fall and winter season. The average annual runoff is about seven times the total reservoir capacity. Since the reservoir is not sufficiently large to regulate or even out the flows over the year, a turbine installation is necessary that can produce power over a wide range of flows. The Ossberger turbines were selected as most desirable in this case as they would produce more power than a Francis turbine. However, there are Francis turbines available from foreign manufacturers in a small size range, such as those manufactured by the Kossler Turbine Company, of Austria which would perform satisfactorily.

A computer program was performed on the inflow data supplied and each month's power and generation computed as well as average annual generation. In determining the amount of energy that could be developed, consideration was given to the effect of the change in head on the turbine units and decreases in efficiency for partial flow conditions. Table VI-1 tabulates the results of the computer studies obtained for four sizes of installation at Painted Rocks. Table VI-1 also presents the estimated capital investment of the four sizes selected and a tabulation of kilowatt-hours per dollar investment. It appears that a minimum of four 1750 horsepower turbines would be desirable for this site with a combined installed capacity of 5200 kilowatts. Four units were selected over three units since the kilowatt-hours versus costs were practically equal and four units would produce more energy (one of the objectives of the work). This would amount to an average annual generation of approximately 16 million kilowatt-hours based on the assumed operating criteria. Tables VI-2 and VI-3 illustrate the type of computer information generated.

TRANSMISSION

Transmission of the power would be made to Darby, a distance of about 22 miles, where it could feed into the 69 Kv line of Montana Power Company. A new 14.4 Kv Line extends from Darby to the vicinity of Painted Rocks Dam. This line could be used for transmitting power from the power plant by increasing the conductor size. There are numerous REA's in the Bitterroot Valley that would be potential purchasers of the energy and capacity. The following communities have REA services indicated as being supplied from the line extending from Darby northward to Missoula: Darby REA, Grantsdale REA, Corvallis REA, Stevensville REA, Victor REA, Ravalli County Electric Coop, Missoula REA, and the Flathead

Irrigation Project of BIA. These potential customers would require use of the transmission line from the power plant to Darby to connect them to the generation facility.

PROJECT COSTS

The Painted Rocks Project Cost was estimated on the basis of installing four Ossberger turbine/generators below the toe of the dam adjacent to the spillway. The existing conduit was assumed to provide a housing for the penstock line and the plant located behind the existing high counterfort wall on the left spillway abutment.

Cost estimates were prepared by computing unit quantities and assigning unit prices to the materials used in the design. Unit prices were based on the engineers' best assessment of the difficulty in reaching the site and comparable prices for the type of work involved. The Cost Estimate presented in Table VI-4 is based on lthe 1977 price levels.

Annual Cost was estimated on the basis of 40-year revenue bonds at 6½ percent annual interest rate. Operation, maintenance and administration was estimated at $50,200 for the four-unit plants and related facilities.

TABLE VI-1

PAINTED ROCKS

Generation vs. Installed Capacity

Installed Capacity KW	No of Units	Design cfs	Penstock Diameter Inches	Avg. Annual Generation $\bar{M}$ Kwh	Estimated Capital Cost of Installation	Kilowatt-hours per $ Investment
2,600	2	310	72	12.03	$ 2,700,000	4.46
3,900	3	480	72	14.35	$ 3,100,000	4.63
5,200	4	684	72	16.07 $0.02 18 mills	$ 3,500,000	4.59
6,500	5	~~688~~ 888	78	17.48	$ 4,200,000	4.16

TABLE VI-2

POWER GENERATION

MONTANA HYDROELECTRIC DEVELOPMENT

PAINTED ROCKS RESERVOIR

1942-1975

JULY 25,1977 BY DAVE ALDEN

POWER PLANT CAPACITY = 5.2 MW

OVERLOAD FACTOR = 1.05

LOSS COEFFICIENT = 0.000025 (LOSS=KQ↑2)

GENERATOR EFFICIENCY = 0.980

TURBINE EFFICIENCY
(FOUR OSSBERGER TURBINES)

% DESIGN FLOW	EFFICIENCY
0.000	0.000
0.020	0.000
0.021	0.600
0.025	0.700
0.050	0.810
0.100	0.840
0.150	0.850
0.160	0.855
0.630	0.855
0.800	0.836
1.000	0.800
1.200	0.750

Q FOR 5.2 MW = 657.1 CFS AT 130.0 FEET STATIC HEAD

Q FOR 5.5 MW = 730.5 CFS AT 130.0 FEET STATIC HEAD

STATIC HEAD (FEET)

OCT	111.0
NOV	94.0
DEC	84.0
JAN	84.0
FEB	94.0
MAR	111.0
APR	125.0
MAY	130.0
JUN	130.0
JUL	130.0
AUG	130.0
SEP	125.0

TABLE VI-3

Typical Computer Calculations

PAINTED ROCKS

1972

MONTH	OUTFLOW CFS	OUTFLOW AF	POWER Q CFS	SPILL AF	HEAD FT	POWER MW	ENERGY MKWH
OCT	99.0	6087	99.0	0	110.8	0.77	0.58
NOV	105.0	6248	105.0	0	93.7	0.70	0.47
DEC	107.0	6579	107.0	0	83.7	0.64	0.47
JAN	105.0	6456	105.0	0	83.7	0.62	0.46
FEB	102.0	5665	102.0	0	93.7	0.69	0.50
MAR	259.0	15926	259.0	0	109.3	2.01	1.45
APR	355.0	21124	355.0	0	121.8	3.07	2.28
MAY	1077.0	66223	730.5	21308	116.7	5.46	4.06
JUN	1610.0	95803	730.5	52337	116.7	5.46	3.93
JUL	264.0	16233	264.0	0	128.3	2.40	1.79
AUG	133.0	8178	133.0	0	129.6	1.22	0.88
SEP	119.0	7081	119.0	0	124.6	1.05	0.78
						ANNUAL ENERGY	17.64

1973

MONTH	OUTFLOW CFS	OUTFLOW AF	POWER Q CFS	SPILL AF	HEAD FT	POWER MW	ENERGY MKWH
OCT	124.0	7625	124.0	0	110.6	0.97	0.72
NOV	107.0	6367	107.0	0	93.7	0.71	0.48
DEC	105.0	6456	105.0	0	83.7	0.62	0.46
JAN	101.0	6210	101.0	0	83.7	0.60	0.43
FEB	99.0	5498	99.0	0	93.8	0.65	0.49
MAR	98.0	6026	98.0	0	110.8	0.77	0.55
APR	343.0	20410	343.0	0	122.1	2.57	2.21
MAY	154.0	9469	154.0	0	129.4	1.41	1.05
JUN	192.0	11425	192.0	0	129.1	1.76	1.27
JUL	127.0	7809	127.0	0	129.6	1.17	0.87
AUG	236.0	14511	236.0	0	128.6	2.15	1.55
SEP	385.0	22909	385.0	0	121.3	3.31	2.46
						ANNUAL ENERGY	12.55

1974

MONTH	OUTFLOW CFS	OUTFLOW AF	POWER Q CFS	SPILL AF	HEAD FT	POWER MW	ENERGY MKWH
OCT	66.0	4058	66.0	0	110.9	0.51	0.38
NOV	75.0	4463	75.0	0	93.9	0.49	0.33
DEC	63.0	3874	63.0	0	83.9	0.37	0.27
JAN	66.0	4058	66.0	0	83.9	0.39	0.28
FEB	66.0	3666	66.0	0	93.9	0.43	0.32
MAR	27.0	1660	27.0	0	111.0	0.19	0.14
APR	141.0	8390	141.0	0	124.5	1.25	0.93
MAY	908.0	55832	730.5	10917	116.7	5.46	4.06
JUN	1941.0	115499	730.5	72033	116.7	5.46	3.93
JUL	317.0	19492	317.0	0	127.5	2.87	2.13
AUG	214.0	13159	214.0	0	128.9	1.96	1.41
SEP	348.0	20708	348.0	0	122.0	3.31	2.24
						ANNUAL ENERGY	16.42

AVERAGE ANNUAL ENERGY 16.15

TABLE VI-4

PAINTED ROCKS DAM

PROJECT COSTS

Feature - Power Plant	Costs
Powerhouse structure	$ 200,000
Penstock Installed	$ 160,000
Conduit Modifications	$ 109,000
Turbine/Generators 4-1300 Kw Ossberger Units	$ 1,300,000
Accessory Electric Equipment	$ 250,000
Switchyard and Miscellaneous Electrical	$ 142,000
Sub-total	$ 2,161,000
Feature - By-pass Valve	
72 - inch Howell-Bunger Valve	$ 250,000
Feature - Roads & Bridges	$ 60,000
Sub-total	$ 2,471,000
Indirects and Overheads	
Contingencies 20%	$ 494,300
Engineering, Administration & Legal ~~20~~ 15%	$ 370,700
Interest During Construction 8%	$ 198,000
TOTAL PROJECT COST	$ 3,534,000
Annual Costs	
Annual Carry Charges for Bond Retirement (40 yrs @ 6½%)	$ 249,800
Annual Operation, Maintenance & Administration	$ 50,200
TOTAL ANNUAL COST	$ 300,000

CHAPTER VII

PROJECT DEVELOPMENT and FINANCING

CHAPTER VII
PROJECT DEVELOPMENT AND FINANCING

PROJECT DEVELOPMENT

General

This chapter provides information on partnership projects, project financing, and potential financial recovery of investment, and recommends future course of action. This report recommends State of Montana development of the proposed projects with a partnership arrangement where the State's partner or partners will operate, maintain and market the power to others within the State. The overall benefits of the projects which may accrue should flow to the people of Montana in the form of repayment of the unsecured debt for State water conservation projects and payment for the non-funded maintenance cost of State water projects which have deteriorated with age.

Partnership Projects

The concept of partnership in the development and conservation of water resources is not new. The principles involved are simple. Whenever local interests, private or public, are able to develop a water resource, it is believed that they should do so. When projects cannot be funded in full by local interests, then the local interests seek a partner which may be a higher level of government or privately-owned utility who will assist them. There is the question regarding sound utilization and conservation of water resources as a natural resource if parties other than the state or federal government are permitted to develop them. To ask this question is to forget the regulatory function performed by various governmental agencies or assume that they do not fairly carry out their assigned responsibilities.

There have been many partnership projects in the United States where Federal, State, local or private interests have combined to develop a project. In many cases the partner provides only the needed funds for the capital investment. That is, the partner provides annual payments to retire the bonds sold to pay for the construction of the facility and, in return, the partner receives the power from the project.

PROJECT FINANCING

Revenue Bonds

There are various means of financing small hydroelectric projects. As indicated previously, one alternative would be to find a power purchaser who is willing to agree to pay an equal annual payment for the entire output of electrical power generated. The payment could be larger than the amount required to finance the construction and could escalate with time as the value of energy increased. A payment larger than the amount needed to retire the debt service and to operate and maintain the facility provides the incentive to the owner to proceed with the project.

Under this situation, if revenue bonds were sold for the development of the project (the most common form of financing), the regulations regarding federal income tax status of the interest on the bonds sold to construct the facilities appears in the Internal Revenue Service Code Section 103(c). This section of the Code indicates that if 25 percent or more of the power is sold to an investor-owned utility, then the interest on the bonds paid to the bond holders will be taxable. The difference in bond interest rate between taxable and tax-exempt bonds may be as much as 2 to 2½ percent. In the following paragraphs related to the financial feasibility, it is assumed that the purchaser of

power would be public-owned districts and the interest on the bonds would be tax-exempt. At the present time, tax-exempt revenue bonds for power projects are being sold at about 6½ percent interest rate (or less). There has been legislation introduced in Congress to amend Sectin 103(c) of the Internal Revenue Service Code to permit all revenue bonds sold for development of hydroelectric projects by public districts to be tax-exempt. If such a bill should pass, public districts such as the State of Montana would not be concerned whether public or privately-owned electrical utilities purchased the power from the partnership project.

Project Financing - Others

Other forms of financing are also available to the State Department of Natural Resources. One part of President Carter's Energy legislation, which was recently passed by the House and Senate (November 1977), pertained to providing federal financial support in the form of grants and loans to encourage the development of hydroelectric power plants at existing dams.

FINANCIAL FEASIBILITY

In Chapters 4, 5 and 6 the capital costs, annual costs, and average annual generation for each of the three projects were presented. Chapter 2 provided information regarding the cost of alternative power resources. From this data, a Benefit-to-Cost determination can be made. Table VII-1 has been prepared to present this data.

From Table VII-1 it can been seen that on an individual project basis, the benefit-cost ratios vary from a high of 1.84 to 1.00 to a low of 0.95 to 1.00. When the three projects are combined into one, the benefit-cost ratio of the combined projects is 1.62 to 1.00.

It should be noted that in-house studies by the Federal Power Commission[1] have indicated that any hydroelectric project with a benefit-cost ratio greater than 0.70 to 1.00 when compared to the alternative cost of generation from fossil-fuel generation should be constructed. This is an arbitrary rule to take into account that over the life of a hydroelectric project, the annual cost remains constant as compared to a fossil-fueled generation plant and the incremental cost of energy (about 1/2 the total annual cost) increases at a rate of about 6 percent per year. In recent years, the incremental cost of energy has increased more rapidly and could very well increase again more rapidly than the six percent.

As an example, let us assume a hypothetical case of a small hydroelectric plant of 6,000 kilowatt capacity and the capability to generate 20 million kilowatt-hours per year. Also let us assume that the capital cost per kilowatt installed is $1200, resulting is an annual cost for such a plant of $820,000[2] to amortize the revenue bonds and $40,000 for operation and maintenance the first year. Each year thereafter, the operation and maintenance cost of the small hydro plant will increase at 6 percent per year. As a benefit, this cost is to be compared to a coal-fired steam-electric generating station. The capacity component is taken at $48/kilowatt-hour per year and the energy components, including operation and maintenance, at 12 mills per kilowatt-hour. This latter variable amount is escalated at 6 percent per year.

On the first year the benefit-to-cost ratio amounts to $600,000 divided by $860,000, or a benefit/cost ratio of 0.70 to 1.00. However, when the operation and maintenance of the hydroelectric plant and the operation, maintenance,

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1/ Re-named Federal Energy Regulatory Commission (Aug. 1977)

2/ Annual Cost based on 40-year repayment period at 6¼ percent

and fuel cost for coal-fired steam electric station are escalated at 6 percent and the present worth of the annual cost streams are compared as shown on Table VII-2, is seen that the true benefit/cost ratio is 1.05 to 1.0 in favor of the small hydroelectric plant.

In conclusions, all three projects studied therefore are financially feasible and should be considered for development.

FUTURE COURSE OF ACTION

The following describes a future course of action for developing the hydroelectric potential of the three sites. In addition, conditions for a suggested partnership arrangement for providing the capital required to develop the projects are outlined.

The first step should be the immediate filing of a Preliminary Federal Power Commission Application on each of the three sites. The purpose of the filing is to secure and maintain priority for a license for the State under the Federal Power Commission Act while procuring data and securing the necessary agreements needed to perfect an Application for License.

The second step is to meet with potential purchasers of power and negotiate a memorandum of understanding between the State and the purchaser. For this step, Bonneville Power Authority should be contacted for their assistance. The steps following will include the preparation of the Federal Power Commission Licnse Application including geological explorations, preliminary designs, Exhibit W (environmental impact report), preparation of water rights application, if necessary, and the negotiation of institutional agreements with various agencies which might be affected by the project such as U.S. Forest Service, U.S. Fish and Wildlife, U.S. Department of Interior, Montana Fish and Game, etc. The institutional agreements should follow after the

conclusion of Exhibit W.

The last phase covers the final design and construction. Generally, final design phase should take about one year. Three months are anticipated for advertising of bids, review, award, receipt of revenue bond proceeds, and notice to proceed. Construction will take about 24 months depending primarily upon the delivery of machinery and electrical equipment.

Partnership Project

It is suggested that the development of the projects will require a power purchaser who will assist in the development of the project with the Department. The project costs, then, will be financed by revenue bonds for which interest and principal payment is guaranteed by an agreement with the power purchaser. It is suggested that if the Department enters into an agreement at this time with a power purchaser, that such agreement will consist of a memo of understanding which contains the following items:

1. Development Funds. Prior to the revenue bond sale, which will occur just before the commencement of construction, development funds will be needed for the engineering, administrative and legal work required to advance the project. It is suggested that the costs required for this work should be provided by the power purchaser. The development funds advanced should be repaid with interest from the proceeds of the revenue bonds sale which would occur before construction commences.
2. Power Revenues. After completion of construction of the project, the power purchaser will pay to the Department in semi-annual payments an amount sufficient to retire the debt service

of the revenue bonds sold by the Department to construct the project and an amount equal to the actual cost of operating and maintaining the project (including the dam). The terms would be set forth in a power purchase agreement which would be finalized prior to the selling of the revenue bonds.

3. Power Generation and Utilization. The purchaser of the power will be entitled to the entire output of hydroelectric energy produced by the project. Transmission of the power should be the responsibility of the power purchaser. It is believed that an agreement for wheeling power can be consummated through the Bonneville Power Act.

4. Additional Payments by the Power Purchaser. In addition to the power revenues, the power purchaser should be required to pay to the Department an annual payment to be negotiated; these funds will be used by the Department to recover a portion of funds which have been advanced by the legislature for other water resources conservation projects which have been constructed to benefit the citizens of the State of Montana.

TABLE VII-1

Benefit-Cost Ratio of Projects

PROJECT:	Broadwater Dam	Deadman's Basin	Painted Rocks
A. COSTS:			
Total Project Cost ($)	14,700,000	3,600,000	3,500,000
Total Annual Cost ($)	1,100,000	282,000	300,000
B. ACCOMPLISHMENTS:			
Installed Capacity (KW)	14,400	2,600	5,200
Average Annual Generation ($\bar{M}$Kwhrs)	78.0	10.3	16.2
C. BENEFIT (in terms of replacement cost)[2]			
@ 26 mills/KWhr	$2,028,000	$267,800	$421,200
D. BENEFIT/COST	1.84 to 1.00	0.95 to 1.00	1.40 to 1.00
E. COMBINED BENEFIT/COSTS ALL PROJECTS		1.62 to 1.00	

[1]Estimated from Operation Studies

[2]From Chapter 2, assumes public-owned generation

TABLE VII-2

BENEFIT/COST RATIO
HYPOTHETICAL SMALL HYDRO
VERSUS
COAL-FIRED STEAM ELECTRIC GENERATION

ECONOMIC ANALYSIS

MONTANA

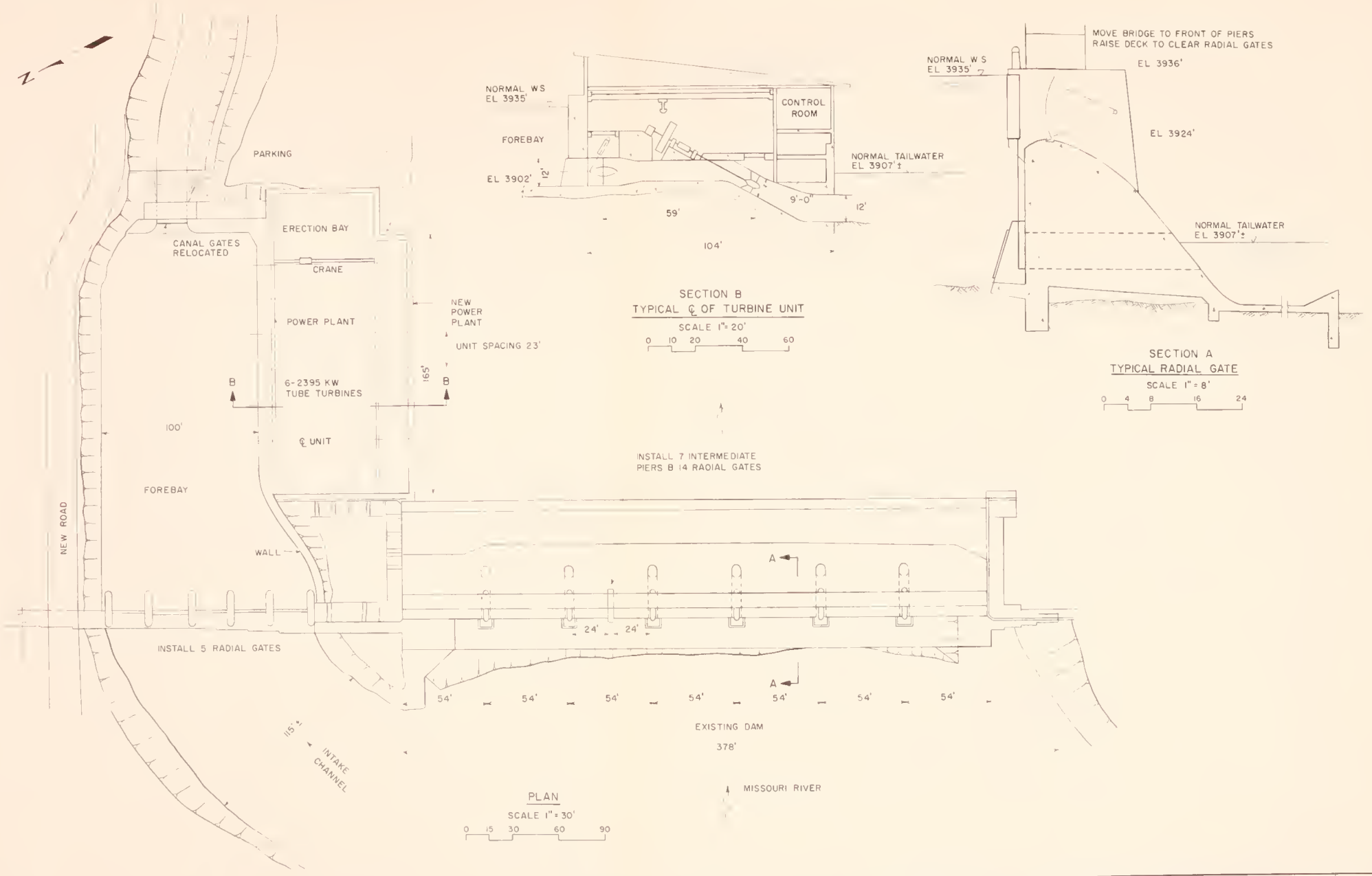
INTEREST RATE = 6.00%

YEAR	SMALL HYDRO COST STREAMS		COAL-FIRED STEAM STATION BENEFIT STREAMS		PWF	PRESENT VALUES	
	CAPITAL COST	O&M COST	CAPACITY	ENERGY[1/]		HYDRO	COAL-FIRED STEAM
1	820000	40000	360000	240000	0.9434	811321	566038
2	820000	42400	360000	254400	0.8900	767533	546814
3	820000	44944	360000	269664	0.8396	726224	528678
4	820000	47641	360000	285844	0.7921	687253	511569
5	820000	50499	360000	302994	0.7473	650488	495428
6	820000	53529	360000	321174	0.7050	615803	480201
7	820000	56741	360000	340445	0.6651	583083	465836
8	820000	60145	360000	360871	0.6274	552214	452284
9	820000	63754	360000	382524	0.5919	523093	439499
10	820000	67579	360000	405475	0.5584	495620	427437
11	820000	71634	360000	429803	0.5268	469702	416059
12	820000	75932	360000	455592	0.4970	445251	405324
13	820000	80488	360000	482927	0.4688	422184	395197
14	820000	85317	360000	511903	0.4423	400423	385643
15	820000	90436	360000	542617	0.4173	379893	376631
16	820000	95862	360000	575174	0.3936	360526	368128
17	820000	101614	360000	609684	0.3714	342255	360106
18	820000	107711	360000	646265	0.3503	325018	352539
19	820000	114174	360000	685041	0.3305	308757	345400
20	820000	121024	360000	726144	0.3118	293416	338665
21	820000	128285	360000	769713	0.2942	278943	332311
22	820000	135983	360000	815895	0.2775	265290	326317
23	820000	144141	360000	864849	0.2618	252410	320662
24	820000	152790	360000	916740	0.2470	240258	315327
25	820000	161957	360000	971744	0.2330	228795	310295
26	820000	171675	360000	1030049	0.2198	217980	305547
27	820000	181975	360000	1091852	0.2074	207778	301068
28	820000	192894	360000	1157363	0.1956	198153	296842
29	820000	204467	360000	1226805	0.1846	189072	292856
30	820000	216736	360000	1300413	0.1741	180506	289095
31	820000	229740	360000	1378438	0.1643	172425	285547
32	820000	243524	360000	1461144	0.1550	164801	282200
33	820000	258135	360000	1548813	0.1462	157609	279042
34	820000	273624	360000	1641742	0.1379	150823	276063
35	820000	290041	360000	1740246	0.1301	144422	273253
36	820000	307443	360000	1844661	0.1227	138383	270602
37	820000	325890	360000	1955340	0.1158	132686	268101
38	820000	345443	360000	2072661	0.1092	127312	265741
39	820000	366170	360000	2197021	0.1031	122241	263515
40	820000	388140	360000	2328842	0.0972	117458	261415
TOTALS	32800000					13847397	14473271

1/ Assumes energy @ 12 mills/Kwhr

$$\text{BENEFIT-COST RATIO} = \frac{14473271}{13847397} = 1.05$$

DRAWINGS



REV	DATE	BY	SUB	DESCRIPTION	APP

REV	DATE	BY	SUB	DESCRIPTION	APP

DESIGNED H.R.M
DRAWN J.S.D
CHECKED H.R.M
IN RESPONSIBLE CHARGE D.C.W

TUDOR ENGINEERING COMPANY
CONSULTING ENGINEERS AND PLANNERS
SAN FRANCISCO CALIFORNIA

BROADWATER MISSOURI RIVER, MONTANA

PROPOSED POWER PLANT

DATE 7-11-77
DRAWING NUMBER

SHEET 1 OF

PLAN
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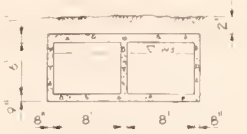

SECTION A
TAILWATER CONDUIT
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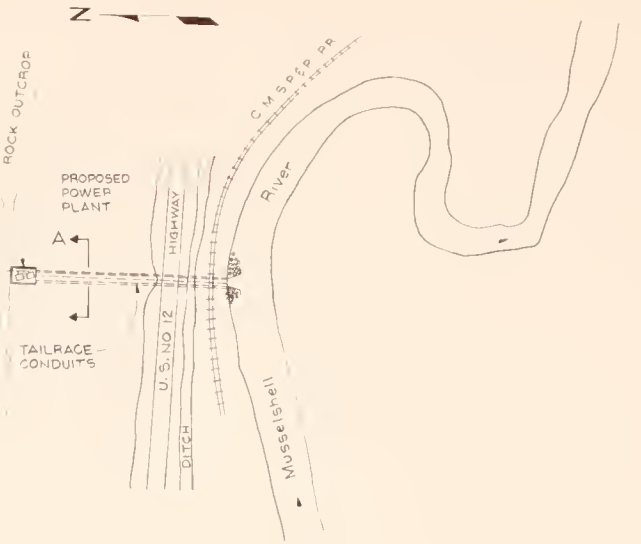

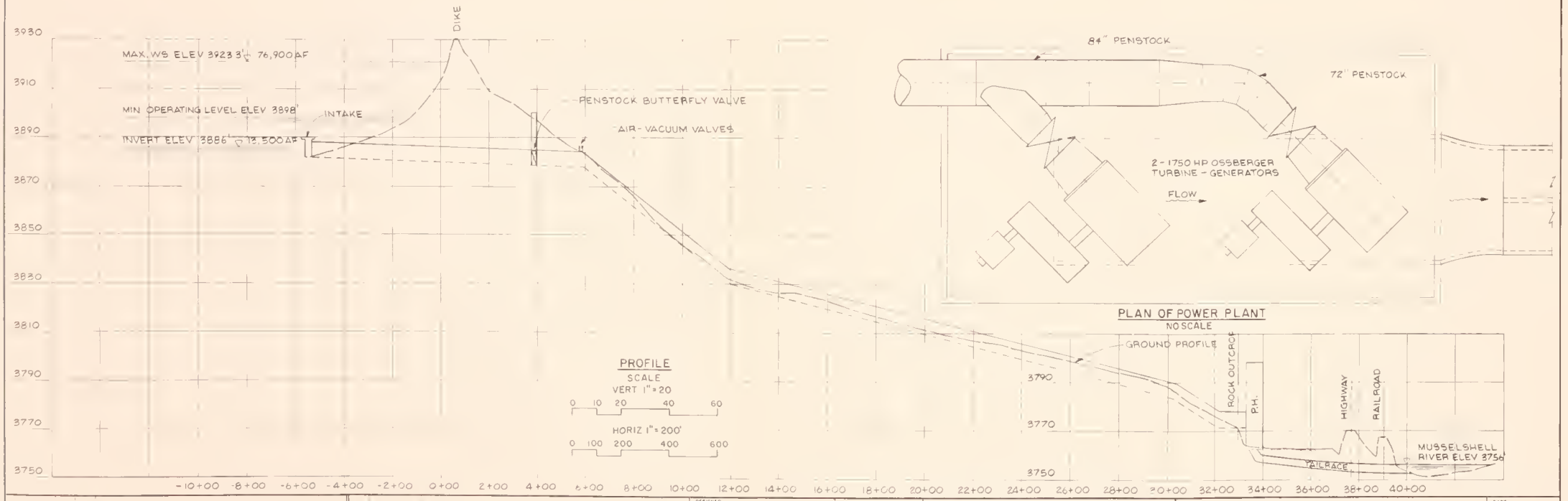

PROFILE
SCALE
VERT 1" = 20
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HORIZ 1" = 200'
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PLAN OF POWER PLANT
NO SCALE

REV	DATE	BY	SUB	DESCRIPTION	APP

REV	DATE	BY	SUB	DESCRIPTION	APP

DESIGNED H R M
DRAWN D E T
CHECKED H R M
IN RESPONSIBLE CHARGE D C W

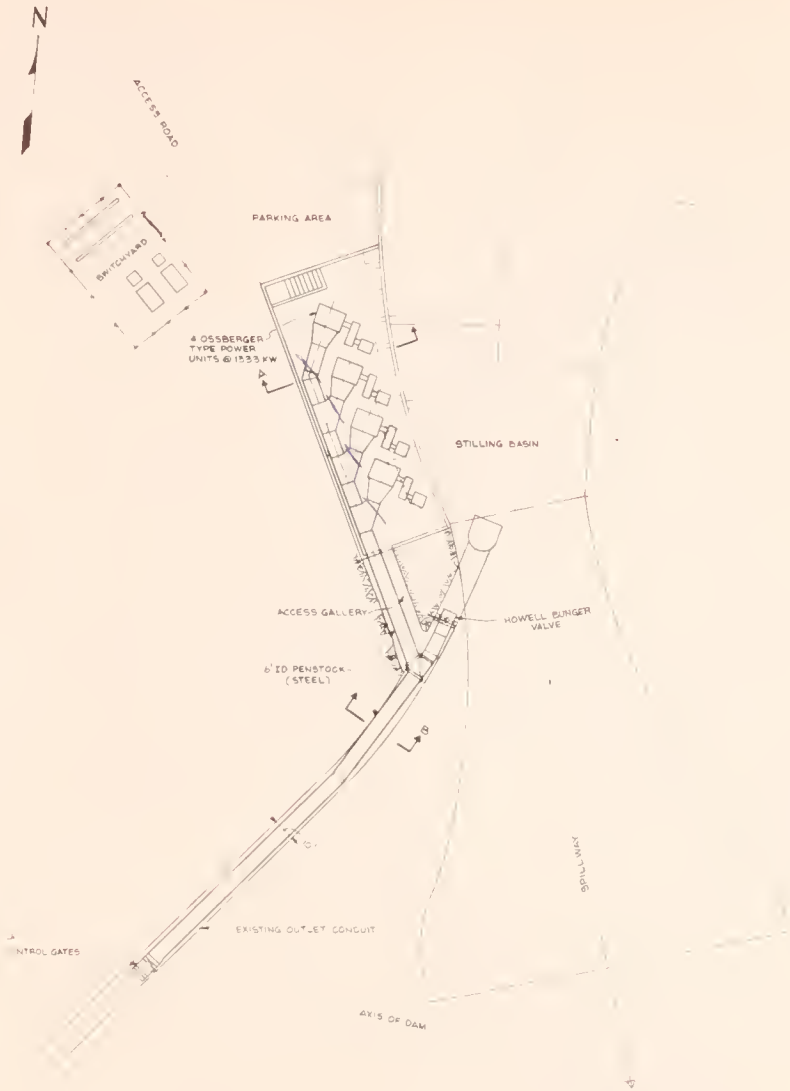
TUDOR ENGINEERING COMPANY
CONSULTING ENGINEERS AND PLANNERS
SAN FRANCISCO CALIFORNIA

DEADMAN'S BASIN, MONTANA

PLAN & PROFILE OF PROPOSED POWER PLANT

DATE 7-11-77
DRAWING NUMBER

SHEET 2 OF



PLAN OF POWER PLANT

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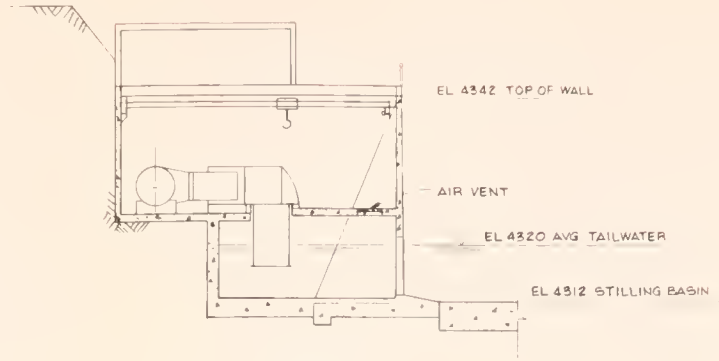

SECTION A
POWER PLANT

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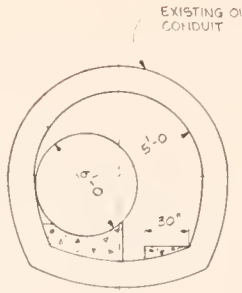

SECTION B

SCALE 1" = 4'

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REV DATE BY SUB DESCRIPTION APP	REV DATE BY UR DESCRIPTION APP	DESIGNED H.R.M. DRAWN D.E.T. CHECKED H.R.M. IN RESPONSIBLE CHARGE D.C.W.	TUDOR ENGINEERING COMPANY SAN FRANCISCO	CONSULTING ENGINEERS AND PLANNERS CALIFORNIA	PAINTED ROCKS DAM, MONTANA PROPOSED POWER PLANT	DATE 7-11-77 DRAWING NUMBER SHEET 3 OF